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ARGONNE NATIONAL LABORATORY
HIGH ENERGY PHYSICS DIVISION

SEMIANNUAL REPORT OF RESEARCH ACTIVITIES

January 1, 1989 – June 30, 1989

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High Energy Physics Division Semiannual Report of Research Activities
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I. EXPERIMENTAL PROGRAM

A. Physics Results

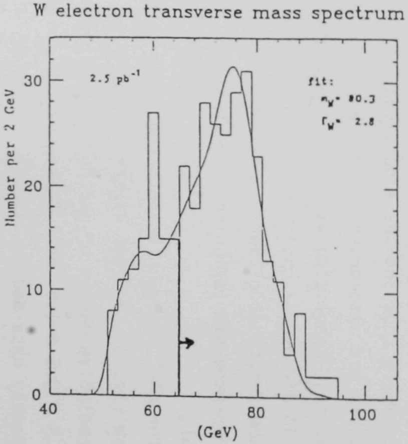
1. Collider Detector at Fermilab

Data analysis continued in parallel with the 1988-89 collider run, and results were presented at the 1989 Baltimore APS meeting on low-Pt physics, electroweak parameters, QCD jet production, and the top-quark search. We summarize below some results from the studies of W and Z boson production.

Figure 1 shows a preliminary analysis of the transverse mass spectrum for $W \to e\nu$. The electrons were selected using the central calorimeter, and the missing transverse energy was required to be larger than 25 GeV, consistent with the neutrino signature. To minimize measurement error on the neutrino energy, an antiselection was made on events with significant jet activity ($E_{jet} < 7$ GeV). The electron energy was calibrated using the central tracking chamber to obtain the average ratio of E/p for electrons. The solid curve in Fig. 1 shows a typical fit; the sensitivity of the fits to choice of structure functions and Pt distribution for the W were explored. The preliminary analysis reported in Baltimore gives a mass value of $M_W = 80.4 \pm 0.6 \pm 1.8$ GeV, consistent with recent results from the UA2 experiment.

The W production mechanisms are also under study. Figure 2 shows a comparison of the jet multiplicity associated with $W \to e\nu$ production and decay. With a threshold of 10 GeV on the observed jet energy, corresponding to ~ 14 GeV parton energy, the fractions of zero, one, two, and three jets are in good agreement with the Papageno simulation and recent higher order calculations by Berends et al.

The mass distribution for e^+e^- pairs, with both electrons produced in the central detector, is shown in Fig. 3. A Breit-Wigner fit, with no systematic corrections for wide angle radiative decays or parton distributions, gives a preliminary Z mass, $M_Z = 90.4 \pm 0.5 \pm 1.8$ GeV. These results are based on only ~ 50% of the full luminosity obtained in 1988-89. (A. B. Wicklund)



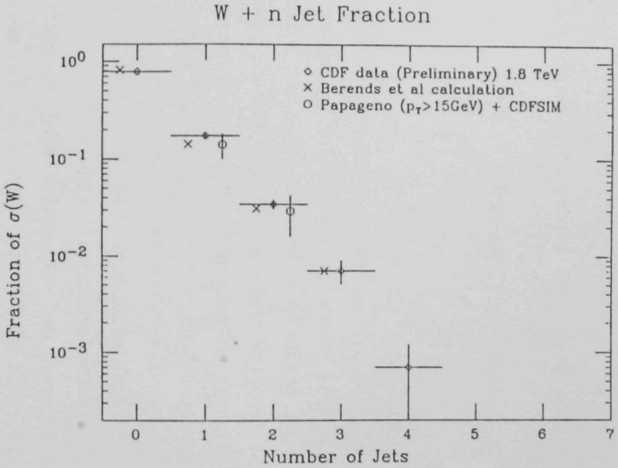


Fig. 1. Preliminary transverse mass distribution for $W \to e\nu$ events with fit to W mass.

Fig. 2. Preliminary jet multiplicity distribution for W + n jets, with n = 0,1,2 predictions from Papageno simulation, and n = 0,1,2,3 predictions from Berends et al.

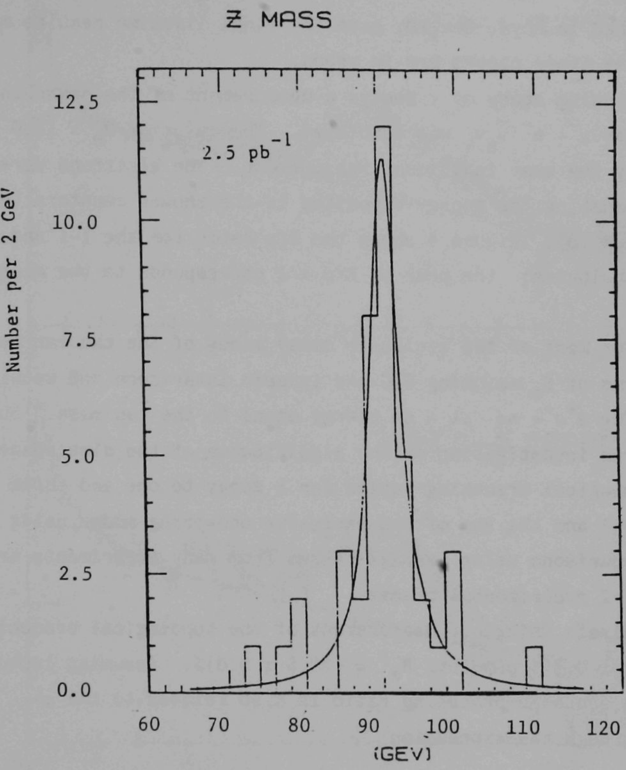


Fig. 3. Preliminary $Z \rightarrow e^+e^-$ spectrum with Breit-Wigner fit.

2. High Resolution Spectrometer

A paper entitled "Measurement of the D^o, D^+ and $_sD^+$ Meson Lifetimes," which was published in Phys. Rev. D, gave the final lifetime results measured in the HRS. Three other papers are in press.

In our continuing study of τ decays a measurement of the branching ratio (B_e) for the decay $\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$ was completed. The value of $B_e = 17.0 \pm 0.5 \pm 0.6\%$ is currently the best individual measurement. The electrons were identified by comparing the energy deposited in the shower counters (E) with the track momentum (p). Figure 4 shows the E/p ratio for the 1-1 and 1-3 charged decay topologies: the peak at E/p = 1 corresponds to the electron signal.

The rates for most of the exclusive decay modes of the tau can be expressed in terms of B_e assuming CVC and isospin invariance and knowing the cross sections for $e^+e^- \rightarrow n\pi$ at a cm energy equal to the tau mass. Such an analysis allows an investigation of the significance of the discrepancy between the topological branching ratios for τ decay to one and three charged prongs (B_1 and B_3) and the sum of the exclusive one-prong modes using the HRS data alone. Comparisons using average values from many experiments are suspect because of experimental biases.

Such an analysis using our measurement of the topological branching ratio $B_3 = (13.5 \pm 0.3 \pm 0.3)\%$ predicts $B_e{}^t = (19.6 \pm 0.8)\%$. Assuming lepton universality the leptonic branching ratio is also related to the τ-lifetime (τ_τ) through the expression

$$B_e = \frac{\tau_\tau}{\tau_\mu} \left(\frac{m_\tau}{m_\mu}\right)^5$$

The HRS measurement of τ_τ together with tau mass and the well known muon mass and lifetime gives $B_e{}^\tau = (18.7 \pm 0.6 \pm 0.9)\%$. Table I compares these different measurements.

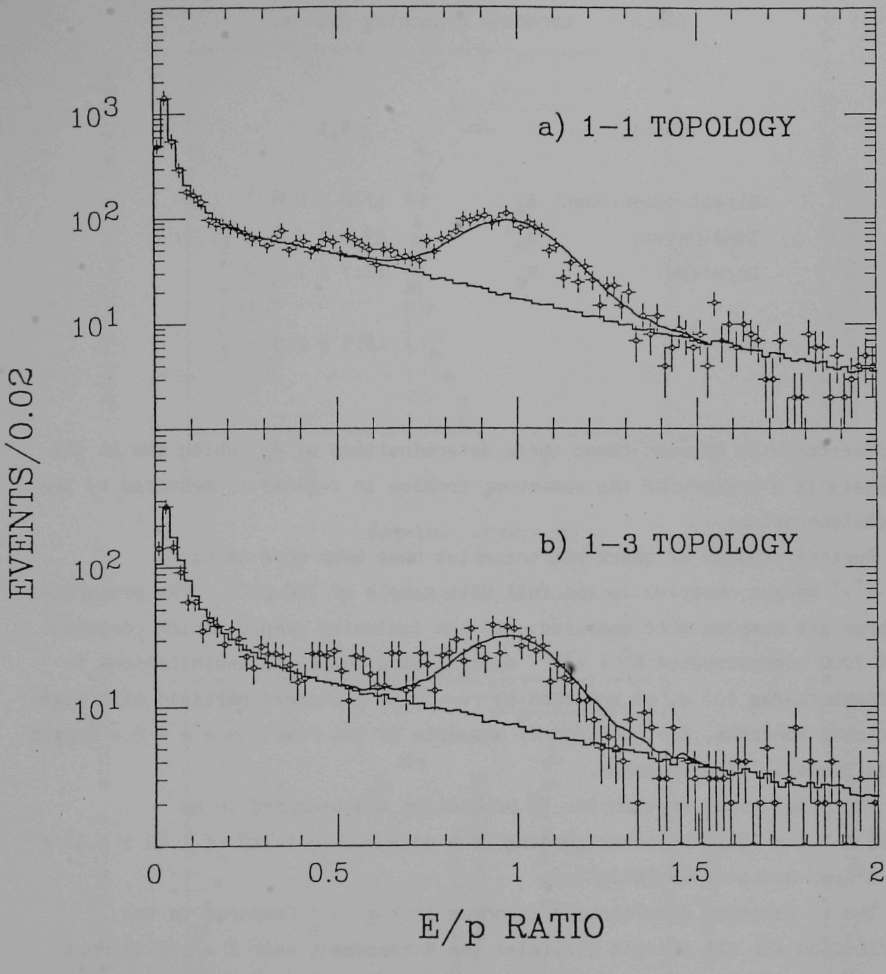


Fig. 4. The E/p ratio for electron candidates from tau decay in (c) the 1-1 topology (b) the 1-3 topology. The histogram is the predicted shape of the background and the full line shows the signal distribution.

Table I. Leptonic branching ratios.

Method		B_e%
Direct measurement	B_e	17.0 ± 0.8
Topological	B_e^t	19.6 ± 0.8
Lifetime	B_e^τ	18.7 ± 1.1
Mean		18.5 ± 0.5

The discrepancies between these three determinations of B_e, which are at the 2σ level, is a measure of the one-prong problem in τ-decay as measured by the HRS collaboration.

Further studies of quark hadronization have been done using $K^0 \to \pi^+\pi^-$ decays observed in the full data sample of 300 pb^{-1}. The properties of three set samples were compared: a) the inclusive sample, which contains about 7000 reconstructed $K^0 \to \pi^+\pi^-$ decays; b) a sample of annihilations to the light quarks (u, d, s) selected by requiring a charged particle with high fractional momentum, $Z > 0.65$ and c) a sample of the reaction $e^+e^- \to c\,\bar{c}$ tagged by the presence of a D* meson.

The total cross section for K^0 production was measured to be (598.8 ± 7.6 ± 18.1) pb corresponding to a mean multiplicity of 1.42 ± 0.02 ± 0.07 K^0 per hadronic annihilation.

The K^0 rapidity distribution is shown in Fig. 5. Compared to the distribution for all charged particles the enhancement near Y = 1.5 is more pronounced for the strange meson. This is a reflection of the significant fraction of K^0 mesons that come from D meson decay. The dip towards Y = 0 also results from the destructive gluon interference effect. Neither the Webber cluster model nor the latest version of the Lund string model reproduces this dip well.

K^{0}, Charged Particle, and Ratio

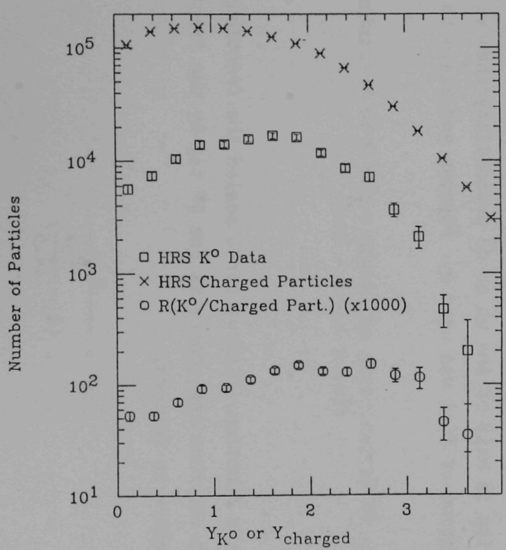


Fig. 5a. K° rapidity distribution compared to that for all charged particles.

Ratio(K^{0}/Charged Particles)

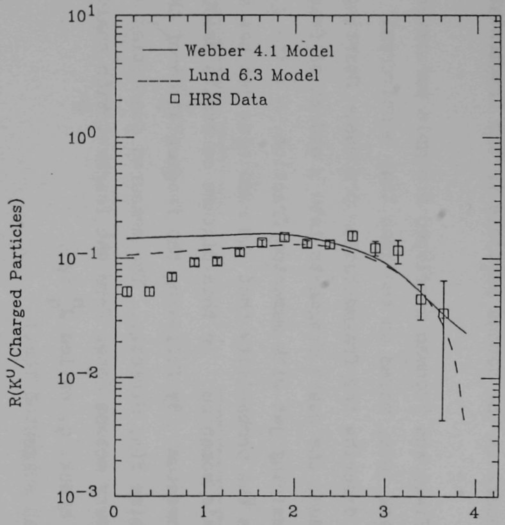


Fig. 5b. Comparison of rapidity ratios to the Webber and Lund models.

The events that are selected with a D^{*+} tag or a high momentum $\pi^{\pm}$ meson must have a d or $\bar{d}$ quark as the second particle in the fragmentation chain as shown in Fig. 6.

Some years ago Field and Feynman developed a simple parameterization of the properties of quark jets, based on the idea that a universal function, $f(\eta)$ could describe the fragmentation process. Starting with a quark of known momentum, the quark fragments into a hadron of fractional momentum z plus a remaining jet with momentum fraction, $\eta = 1 - z$. The function, $f(\eta)$, gives the probability that the remaining jet has a fraction, η of the original quark's momentum. In this picture $c\bar{c}$ events produce a D^* plus a d quark of known momentum. By following the fragmentation of these known d quarks, we can determine $f(\eta)$ directly. The measured quantities are the distributions of primary mesons (ones from the fragmentation chain directly) of flavor, h, from a quark, q, called $D_q^h(z)$.

Field and Feynman suggested that:

$$D_d^{\pi+}(z) - D_d^{\pi-}(z) = \gamma f(1 - z) = \gamma f(\eta)$$

where γ is the probability of $u\bar{u}$ or $d\bar{d}$ quark being produced from the vacuum. If the $s\bar{s}$ probability is half of the $u\bar{u}$ or $d\bar{d}$ probability then $\gamma = 0.4$. A simple parameterization of $f(\eta)$ was used by Feynman and Field to fit electro production data:

$$f(\eta) = 1 - a + 3a\eta^2$$

with a = 0.88.

To determine the function, $f(\eta)$ we first scaled the fractional momentum of each particle in the same hemisphere as the D^* tag by the fractional momentum of the d quark as follows.

$$z' = \frac{z}{\left(1 - \frac{P_{D^*}}{14.5}\right)}$$

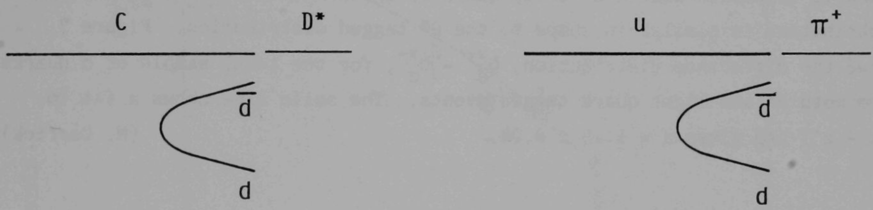


Fig. 6. Hadronization of C and u quarks to give leading D* and π^+ mesons.

where z' is the fractional momentum relative to the d quark momentum. The subtracted positive charge and negative charge distributions, then are fit for the function, f(1 - z') as in the equation above. As expected for light quark fragmentation the f(1 - z') is large for large η (small z'). That is, most of the time the remaining quark carries off the majority of the momentum.

A similar analysis was also done for the light quark tagged events where a majority of the events are from $u\bar{u}$ fragmentation and where the remaining quark is therefore also a d (or $\bar{d}$) quark of known momentum. The difference distribution is similar in shape to the D* tagged distribution. Figure 7 shows the difference distribution, $D_d^{\pi+} - D_d^{\pi-}$, for the total sample of d quarks from both D* and light quark tagged events. The solid line shows a fit to f(1 - z') and gives a = 1.15 ± 0.04. (M. Derrick)

3. Computational Physics

The computational physics effort continued to be devoted to simulations of Lattice Gauge Theories with dynamical quarks. Our primary thrust continued to be the simulation of Lattice Quantumchromodynamics (QCD) aimed at a better understanding of the physics of Hadrons and Nuclear Matter. Our secondary goal was to simulate the recently found strong coupling phase of QED using the techniques developed for Lattice QCD. The method used for both Lattice QCD and Lattice QED, continued to be the hybrid molecular dynamics method. The computers used for these large scale simulations were the HEP division's ST-100, the ETA-10 at SCRI, the CRAY Y-MP at PSC, the CRAY 2S at NCSA and the CRAY X-MP, CRAY 2 and CRAY 2S at NMFECC. During this period we started preparing codes to run on the CM-2 at NCSA. This development was done on the CM-2's at Argonne's ACRF and at CMNS.

We continued our studies of the finite temperature phase transition of QCD, extending our studies of the light quark region to larger lattices ($12^3 \times 4$) to reduce the finite lattice size artifacts. Two studies were performed. In the first, the theory with 4 degenerate quark flavors of mass m = .025 (lattice units) was studied, and the phase transition from nuclear matter with its spontaneously broken chiral symmetry to the chirally symmetric quark-gluon

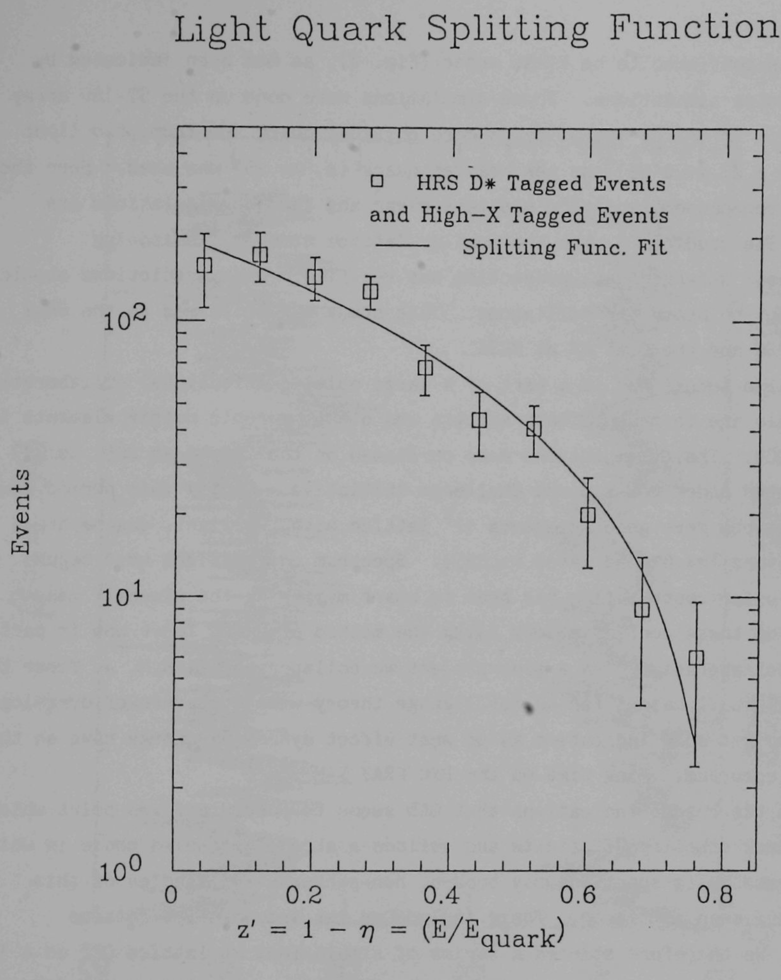


Fig. 7. Light quark splitting function compared to Feynman and Field prediction.

plasma was confirmed to be first order (Fig. 8), as had been indicated by small lattice simulations. These simulations were done on the ST-100 array processor. In the second study, a more physical quark spectrum, two light quarks (u & d, m=.0125) and one heavier quark (s, m=.25) was used. Here the order of the phase transition was less clear and further simulations are needed. The prediction from the smaller lattice studies, indicating considerable strange quark production was verified. Such predictions should be relevant to heavy ion collisions. This study was performed on the CRAY Y-MP at PSC and the CRAY 2S at NCSA.

We also functioned as a part of a large multi-institutional collaboration whose goals are to measure mass spectra and other hadronic matrix elements in Lattice QCD. These simulations were performed on the ETA-10 at SCRI using time granted under DOE's Grand Challenge initiative. During this period gauge configurations were generated on a 12^4 lattice with two light, degenerate quark flavors (m=.01 and later m=.025). Spectrum calculations were begun. Our particular contribution has been to start measuring the glueball mass spectrum on these configurations using the method of M. J. Teper who is part of the collaboration. As a side project we collaborated with M. J. Teper to measure glueball masses for an SU(2) gauge theory with 4 flavors of dynamical quarks, to get some indication as to what effect dynamical quarks have on the glueball spectrum, using time on the PSC CRAY Y-MP.

With the recent indications that QED seems to posess a fixed point which renders weak coupling QED finite and defines a strongly coupled phase in which chiral symmetry is spontaneously broken, non-perturbative studies of this theory have been initiated. These include as yet inconclusive lattice studies. We therefore started a series of simulations of lattice QED on a 16^4 lattice in order to attempt to clarify the situation. The Argonne ST-100 was, and continues to be used for these studies. During this period we commenced coding this problem for the Connection Machine (CM-2) where we hope to continue these simulations at smaller electron masses than is possible on the ST-100. The code development has been done on the ACRF and CMNS CM-2's and production running will be done on the NCSA CM-2. (D. Sinclair)

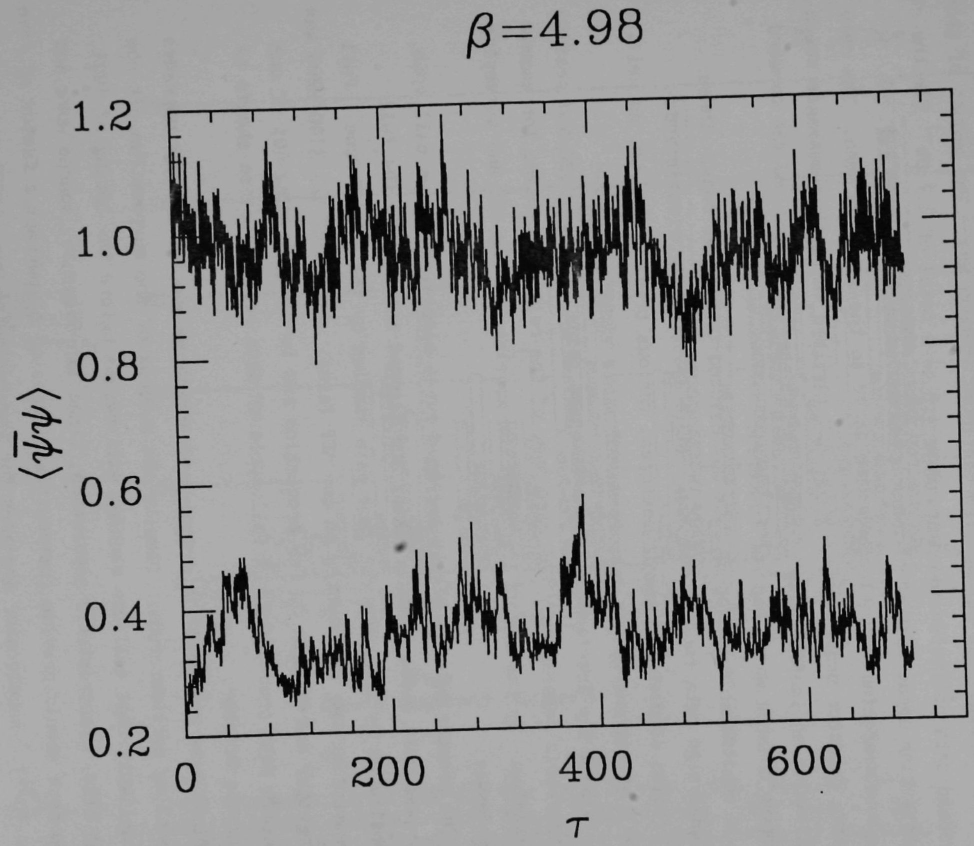


Fig. 8. Time evolution of 4 flavor QCD from hot and cold starts showing evidence for coexisting states indicative of a first order transition.

B. Experiments Taking Data

1. Collider Detector at Fermilab

The collider run at Fermilab continued through May. The amount of good standard data collected increased from 1.8 to a total of 4.7 pb^{-1} for the run, representing about half the luminosity produced by TeV-I (see Fig. 9). Triggers searching for τ leptons were added to the standard menu. The only notable detector problems were a bad ALU involved in Fastbus messages which resulted in an inefficiency of about 7% in data collection and the forward tracking chamber which was not restored.

A considerable amount of time was devoted to special runs. These included high beta running for small angle spectrometer elastic and diffraction studies at several energies, various trigger studies, as well as 10 nb^{-1} of low energy jet data for a QCD scale violation test.

In June the accelerator turned to phase space tests for SSC and testing electrostatic separators. CDF used some of the related downtime for cosmic ray studies. By the end of the month the accelerator was off and surveying was underway.

The processing of a highly selected event sample, which we call spin, kept reasonably close to data taking and allowed essentially the full luminosity to be available for some data samples by the end of June. Full reconstruction was implemented on two ACP farms. A farm of VAX 3100/3200 was put together and brought up for production and is now providing 40% of our production data processing. A full cycle of data reconstruction should be complete in October.

Plans have been made in a series of workshops and reviews for upgrades for upcoming collider runs. Despite the success of the current run, it now seems unlikely that collider running will resume before the Spring of 1991. At that time, electrostatic separators, linac improvements, source work and new low beta should provide luminosities increased by perhaps a factor of five (peak ~ 10^{31}). Accelerator upgrades for the following run (1993) will involve increasing the number of bunches such that crossing times will be 400 ns instead of the current 3.5 μs. An additional luminosity increase of 2-4 is anticipated for that run, with luminosity eventually exceeding 5 > 10^{31}.

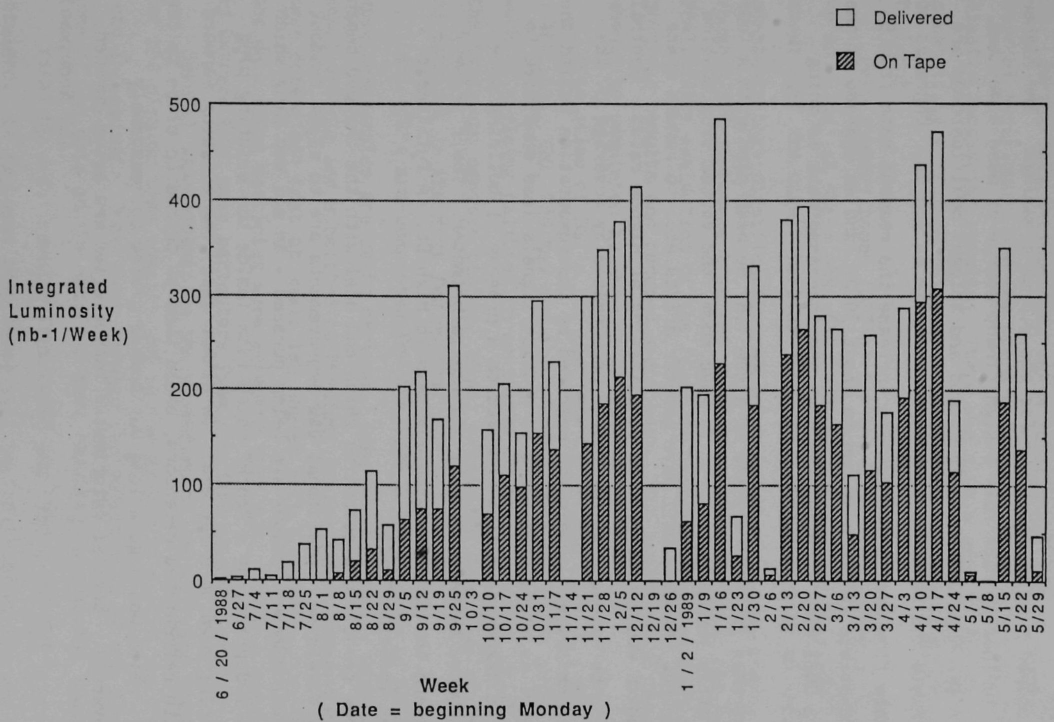


Fig. 9. Data accumulation by CDF for the 1988/89 run: the recovery from the Christmas shutdown was a bit dissappointing. The lull at the beginning of May reflects special runs at lower energy, high beta, etc.

During the past run, the first level trigger operated on a 7 μs cycle, using beam-beam counters as a pretrigger for the 3.5 μs crossings. The higher than anticipated luminosity made this a significant source of dead time, and not at all viable for the 1991 run. Front end and trigger modifications are in progress to enable the first level trigger to cycle at 3.5 μs. Upgrades to scan times and data flow are in progress to increase the readout rate from 5-10 Hz which was possible in the past run to about 30 Hz, and an upgrade of the Level-3 farm to a UNIX/RISC farm to deal with the increased data is being pursued.

Detector upgrades for 1991 consist of a new 1.5" Be beam pipe with a four layer, 50 μ, Si strip vertex detector. To make room, the vertex TPCs must be replaced, and the new chambers will have shorter drifts etc. to reduce space charge effects which would otherwise be debilitating at higher rates. Central muon coverage will be extended to add to the pseudorapidity coverage of the current central muon trigger scheme and upgraded by instrumentation behind the return yoke as well as steel side walls to provide signals less sensitive to punch through. At Argonne, we have embarked on a program of building wire chambers to be mounted between the coil and the calorimeter. Their primary mission is to extend the single photon analysis to high Et. A full scale prototype chamber is being built.

For 1993, new front end electronics which can deal with the changed bunch spacing is being developed. Additional DAQ improvements are to allow readout at 100 Hz. Two calorimeter options are being pursued - an all new plug which covers down to ~ 2 degrees, or a "cork" which fits inside the existing plug calorimeter covering down to 2 degrees. In either case, the existing forward muon toroids, with refurbished detectors, could then be pushed up close to the central detector, which would go a long way toward giving us reasonably complete muon coverage. Several calorimeter technologies are being pursued.

(L. Nodulman)

2. Spin Physics at LAMPF

During this period there was a substantial amount of data analysis on several experiments and the preparation of a short paper on some of the np elastic scattering results. There was also a trip to Saclay to evaluate the possibility of future collaboration with the nucleon-nucleon group of F. Lehar.

Data summary tapes (DST's) for the E-665 measurements (C_{LL}, C_{SL} for np $\to$ np and $\to d\pi^\circ$ at KE_n = 484, 634, 788 MeV and $\theta_{c.m.}$ = 80 - 180°) were made for about half the data. Earlier DST's were generated with an error in some constants that significantly reduced the number of good events retained. A roughly 30% improvement in the reconstruction efficiency has been achieved. Preliminary evaluation of the final C_{LL} values indicated good agreement with previous results and reduced error bars. The remainder of the DST's for E-665 should be completed by the end of the year.

Production of DST's for the 1984 E-770 data (C_{SS}, C_{LS} for np $\to$ np at KE_n = 484, 634, 720, 788 MeV and $\theta_{c.m.}$ = 40 - 90°) has begun after considerable work on deriving calibration constants for drift chamber delay lines and for the hodoscope counter timing. Final values for a portion of the data should be obtained in the next few months.

All DST's are completed for the 1985 E-770 np elastic data, and final spin observables are being derived. Some of the results were written in a short article and submitted to Physical Review Rapid Communications. It has been determined that at small lab angles both C_{NN} and C_{SS} can be obtained from the data since particles were detected over much of the ϕ range. The software to extract both spin parameters from the data is being written.

Several improvements in the procedure to estimate the background shape for the missing mass spectra and in the method to derive the final values have been introduced. These have reduced the sensitivity of the final values to some of the cuts on the data and have resulted in somewhat smaller error bars.

Final np $\to d\pi^\circ$ results from E-665 and 1985 E-770 DST's are being obtained. It is hoped that these will be finalized by the end of the summer. A paper is being prepared on the data, and comparison to other measurements and to phase shifts show good agreement in regions where the data overlap.

The analysis of the E-960 measurements of $\Delta\sigma_L$ is progressing very well. Nearly final values have been obtained at 634 and 567 MeV. The expected correlations of the measured asymmetries with the fraction of the beam that was bunched have been observed using the full data sets. Some small systematic errors have been seen which have been traced to differences in the size of the proton beam at the neutron production target, correlated with the beam spin. The first pass analysis of the data to locate bad beam spills has been completed for the 484 and 788 MeV data, and final results at these energies will be obtained in the next few months. Problems are anticipated with the 720 MeV data, since no monitor of the bunched beam fraction was available during these runs. A New Mexico State University graduate student and an Argonne physicist are working on the analysis. It is anticipated that all the data and the Ph.D. thesis will both be finished by the end of the year.

Discussions have begun with physicists working on nucleon-nucleon scattering at Saclay for a possible collaboration in the future. An Argonne physicist visited Saclay during an experimental run in March and learned about some of the needs of the present collaboration in terms of manpower and hardware. A decision on whether to join the Saclay collaboration will be made in the next few months. (H. Spinka)

C. Experiments in Preparation Phase

1. Nucleon Decay

Summary

The Soudan 2 experiment passed several important milestones during the first half of 1989. The upgrade of the first quarter of the detector was completed with the replacement of thirteen of the oldest modules. The first three halfwalls on the West side of the detector were installed and brought into operation. (A halfwall is a subassembly of eight 5-ton modules, stacked four across and two high.) Ten new active shield panels were turned on: 62% of the shield is now in operation. Two more calibration runs at the ISIS test beam were completed. Eight U.S. and eight U.K. 5-ton modules were delivered to the mine site, and the four oldest modules removed from the detector were returned to Argonne to be rebuilt. This brings the total number of 5-ton modules in the underground laboratory to 97 (417 tons), and the number of installed modules to 88 (378 tons).

Detector operation

The Soudan 2 experiment recorded data for 113 days of livetime, giving a duty cycle of 62% during the first half of 1989. This brings the total exposure to 215 days, or 8.3% of a fiducial kiloton year for contained events. A total of ten neutrino interaction candidates have been identified in this data set. This neutrino interaction rate is consistent with expectations based on Monte Carlo calculations of the effects of containment cuts and detection efficiency.

The Soudan 1 experiment continued to accumulate cosmic-ray data for muon astronomy in 1989. The surface array resumed operation in coincidence with Soudan 1 in April, following the winter shutdown when it was not operated due to cold weather. The surface array measures the energies of primary cosmic-ray interactions, and is expected to be useful in determining the nuclear composition of the cosmic-ray primaries which produce underground multiple muon events.

Ever since the Soudan 1 claim of an excess flux of underground muons from the direction of Cygnus X-3, there has been much controversy over the question of whether astrophysical objects emit particles which produce high energy muons. During the first half of 1989, two X-ray pulsars produced large bursts of energy which were recorded by instruments on the Earth's surface. On February 23 a large flux of high energy particles from the the Crab pulsar was observed by extensive air shower arrays at Baksan (USSR) and Kolar (India). On June 2 the Cygnus X-3 system produced an 18 Jansky outburst of radio emissions, which was the first radio burst recorded since the fall of 1985. A large signal was observed in Soudan 1 during the 1985 Cygnus X-3 radio event. The data from Soudan 1 and Soudan 2 are now being examined for signs of excess muon flux from these objects during the burst periods.

Activities at the Soudan Mine Site

A significant improvement in the performance of the first quarter of the detector was obtained by replacing thirteen 5-ton modules, including all eight of the modules in the first halfwall. This halfwall had been in operation for nearly two years, and four of its modules were of an early design whose geometry was incompatible with newer modules. In addition, some of the modules in this halfwall would not operate above 7 kV drift voltage, giving a lower drift velocity than in other halfwalls. The four old-style modules were returned to the Argonne module factory for recycling of their corrugated steel sheets. The repair of the 17 other modules removed from the detector over the past nine months was completed at the Soudan site and all have now been reinstalled in the operating detector. There are now no unplugged anode signal cables, and all modules operate at the same 9 kV drift voltage.

A second major project at the mine site was the assembly of the first three halfwalls of the second quarter of the detector, which is being built on the West side of the detector support structure, adjacent to the first quarter. Until now there has been no operating electronics on the West side, due to cost-saving strategies of two years ago which allowed the first quarter of the experiment to be turned on rapidly. West-side electronics made operational included the final three CAMAC crates, which required an extension of the serial highway. The final eight crates of cathode ADC electronics were completed by the Argonne electronics group and installed to read out the new halfwalls. This completed the installation of the system of 24 crates of ADC's needed to read out the full 1100-ton detector. All future halfwalls will have their signals summed with those of existing halfwalls before digitization. The high-voltage power-supply system for the second quarter of the detector was installed and brought into operation, including backup power and remote control electronics and software.

In order to operate the first West-side halfwalls all 8 crates (128 16-channel cards) of anode receiver amplifiers were replaced. The new amplifiers, which were designed and built at Argonne, have special 2-fold summer front ends to sum anode signals from East and West halfwalls prior to digitization. The old anode amplifiers were then modified at Argonne for use with the West-side cathodes, and are now back in service. The anode receiver amplifier swap was completed in a single day through the use of special pulser calibration system software which allowed the gains of all 2048 channels to be checked quickly. The new calibration software was also used check the operation of the bilinear ADC conversion, which has now been turned on in all 5888 operating ADC channels. This change extends the dynamic range of the 6-bit ADC's by using a less sensitive conversion gain in the upper half of their range.

A third major project at the mine site was the turnon of ten new panels of active shield modules. This involved completion of gas plumbing, repair of leaks, installation of preamplifiers and cabling, and turnon of new CAMAC readout electronics. In addition, the installation of active shield manifolds over the entire West floor and in the the first four "crack filler" assemblies was completed. The crack-filler assemblies cover the 11-inch wide access spaces which separate adjacent shield wall panels. At the end of June, 896 active shield manifolds were in operation, which is 62% of the full complement of 1456 modules. This includes complete coverage of the ceiling and three walls, and nearly doubles the area of the operating shield since the first of the year.

Other activities at the underground laboratory included the installation of the third and fourth 8-mm cassette tape drive, making it easier to copy Soudan 2 data for distribution to the collaborating institutions. All data are now recorded and distributed on 8-mm cassette tapes, saving tens of thousands of dollars in tape and shipping costs every year. The computing power in the underground laboratory was increased with the installation of a second VAXstation 3200 computer, giving a total of five VAX computers in the local cluster. The third gas recirculation and purification system was installed to service the first four West-side halfwalls, and the monitor system was expanded to include both this rack and the active shield gas system.

An important milestone was passed in June with the start of automatic processing of the data recorded on every run as soon as the run ends. This processing includes track reconstruction, identification of contained-event candidates, and accumulation of tube-hit summary information. The processed events will be distributed along with the raw data to the collaborating institutions where various types of physics analyses are being performed. The event reconstruction processing places a severe load on the mine VAX cluster, which will be upgraded soon to provide more computing power. Three more disk drives were installed, and the load on the VAX 11/750 data acquisition computer was lightened by moving the 8-mm tapes, modems, and some terminals to the two VAXstation 3200's. Uninterruptable power supplies were also installed on several disk drives to permit automatic resumption of data taking following short power outages during summer thunderstorms.

Considerable effort was devoted to the design of a new cleanroom for 5-ton module assembly. The present cleanroom is a temporary wood and plastic-sheeting structure which will have to be moved within the next year to make room for the growing detector. The new cleanroom will be constructed on an elevated steel platform over the work area at the North end of the detector. It will be under crane coverage and within the active shield enclosure. It will provide a larger and cleaner work area and eliminate the fire hazard of the present wooden structure. It is planned to complete most of the construction work before the end of 1989.

Soudan Activities at Argonne

The Argonne module factory completed the assembly of eleven 5-ton module stacks (through Module #78) and twelve pairs of readout planes (through Module #77). Eight U.S. modules have been shipped to the mine so far this year, and three old U.S. modules have been returned, giving a total of 59 U.S. modules underground. The number of modules built was lower than planned because module production was stopped in mid May when it was discovered that the most recent order of plastic insert sheets was contaminated with an electronegative poison. Inserts are the formed polystyrene insulators which surround each corrugated steel sheet, to provide additional protection against drift high voltage breakdowns. Delivery of inserts from a new production run, which is being carefully monitored for poison at every step, is expected in mid July.

The changeover from G-10 to less radioactive readout-plane materials has moved into production with the arrival of 100 cathode boards made of the new CEM-1 material. CEM-1 is only about 20% as radioactive as G-10 and has similar mechanical properties. Cathode boards for two modules have been made from the new material so far.

Module #58 continued to accumulate data on the Argonne module-factory cosmic-ray test stand. Data were collected to increase the sample of stopping muons, and the analysis effort continued to obtain the pulse height variation along stopping muon tracks. Three hundred events were eventually isolated, and analysis of this sample confirmed the earlier finding that the track direction can be correctly determined for 86% of stopping muons. Figure 10 shows the measured increase in the ionization of cosmic-ray muons as they range to a stop in Module #58.

Following this study, the test-stand module gas was changed from the standard 85%-argon/15%-CO_2 mixture to 88%-argon/10%-CO_2/2%-methane. As expected, lowering the fraction of CO_2 raised the drift velocity from 0.6 to 0.9 cm/μsec, while the addition of methane compensated for the reduction in quenching of readout plane pulses. The drift velocity in Soudan 2 is lower than originally planned because of the presence of water, which has proved to be difficult to remove from the module gas. Although the addition of methane to detector gas in the mine would complicate gas handling procedures, the higher drift velocity will improve the performance of the detector: it decreases event size and accidental rates and reduces the loss of drifting ionization electrons by decreasing the drift time.

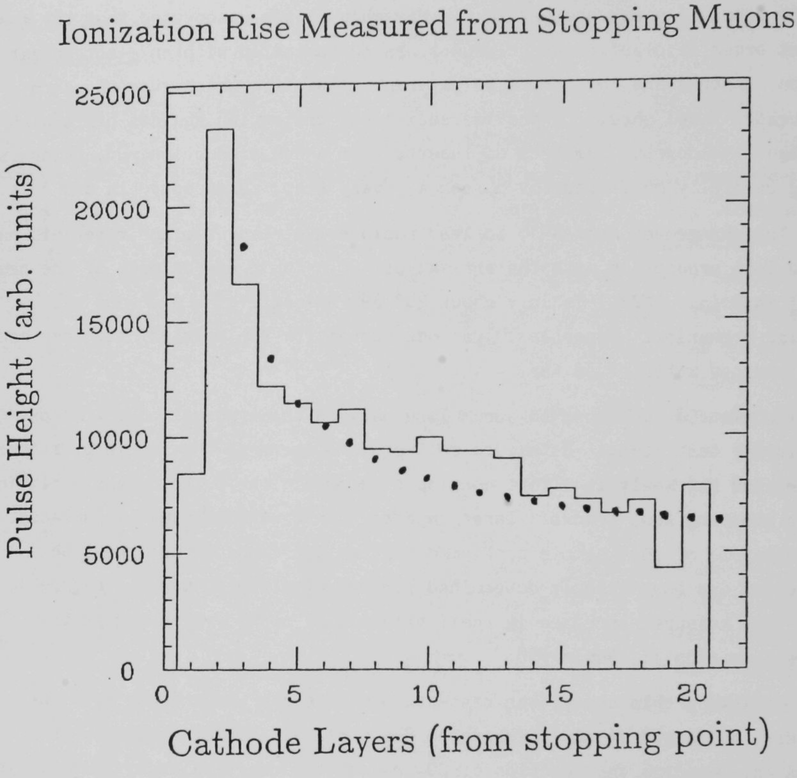


Fig. 10. The measured ionization rise from cosmic-ray muons as they range to a stop in a Soudan 2 module at the Argonne cosmic-ray test stand. The superposed points show the behavior predicted by the Bethe-Bloch equation.

The Argonne electronics group continued to devote a substantial effort to Soudan 2, particularly to complete the assembly and checkout of the new West-side electronics described above. In addition, a replacement of the DC-DC converters used in the anode high voltage distribution system at the mine has begun. The original converters had a higher than expected failure rate under high voltage, increasing down time and maintenance costs. Existing distribution boxes are being retrofitted with the new converters as failures occur. New anode high voltage distribution boxes are being constructed with twice as many outputs as the original design so that they can supply independent voltages to top and bottom modules in halfwalls. Studies of prototype high voltage decoupling and distribution fixtures were made on the Argonne cosmic-ray test stand to check for signal degradation. Prototype fixtures to supply separate top and bottom voltages on one face of a halfwall at the mine are now being built.

Following successful testing of the new edge trigger daughter board prototypes on a full 256-channel crate at the mine, the Argonne electronics group began production of enough boards to instrument all 24 crates. Currently the edge trigger electronics is implemented only on the eight anode crates, but it will be needed on the cathodes as well in order to maintain high efficiency and a low trigger rate as the detector grows. Finally, component orders were placed for the summer electronics and for calibration electronics for the second quarter of the detector.

Argonne physicists continued to play a major role in installation, turnon, and data acquisition activities at the Soudan mine site. Installation and checkout of the electronics for the West side of the detector was a particularly important project during the first half of the year, and culminated in the successful readout of cosmic-ray data from the first West-side halfwalls.

Argonne physicists completed work on a more efficient contained-event filter, and a substantially improved version is now in routine use. The filter is used to identify contained-event candidates at the end of every run, and its output is scanned by physicists to identify neutrino interactions.

The higher noise rejection of the new filter algorithms has substantially reduced the scan load. During 1989, the analysis of contained-event data from Soudan 2 has focussed on developing well-defined criteria for identifying neutrino interaction events, making use of all available information from the events which pass the contained-event filter and physicist scan. This task is currently more difficult than it will be eventually because the active shield was only partially operational, and was completely inoperative for a few weeks due to installation work. Finally, Argonne physicists have started work on the analysis of cosmic-ray multiple-muon events and on a search for massive magnetic monopole tracks in Soudan 2 data.

Soudan Module Calibration at ISIS

The collaboration continued to devote a major effort to the study of Soudan 2 5-ton modules in the ISIS charged-particle test beam at Rutherford. U.K. Module #31, which had been used in the previous test beam run, was replaced by U.K. Module #38. The test beam readout electronics was upgraded to be identical to that used at the Soudan mine site, and a new procedure was developed to optimize the readout plane gas gain by measuring the apparent attenuation of drifting ionization electrons versus anode wire voltage. The two 1989 exposures more than doubled the previous data sample of positive and negative pions, muons, and electrons between 170 MeV/c and 400 MeV/c. Figures 11 and 12 show a stopping muon and an electron shower recorded at the ISIS test beam. Further test beam calibration runs are planned for the summer, after which the beamline and module support will be reconfigured to allow the beam to be brought in through the bottom of the module, perpendicular to the drift tube planes, to extend the response studies to the full range of track orientations.

The Soudan 2 collaborators were saddened by the unexpected death on April 20th of long-time Park Manager Don Logan. The Soudan 1 and Soudan 2 experiments would not have been possible without his enthusiastic support.

(D. Ayres)

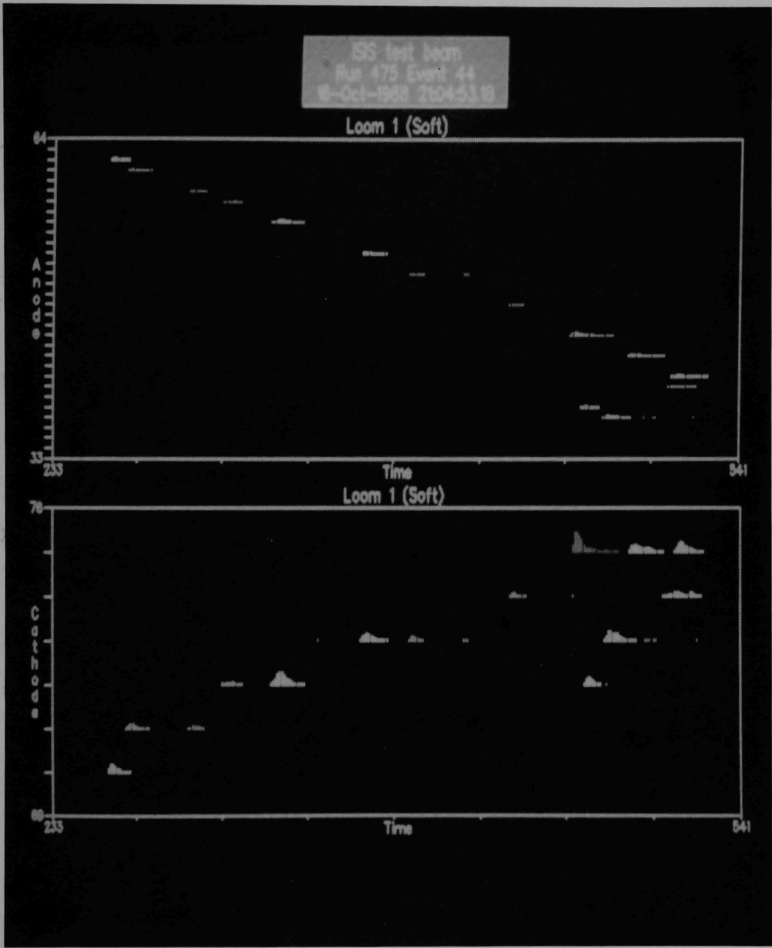


Fig 11. Two orthogonal views of a positive muon stopping and decaying in a Soudan 2 module in the ISIS test beam at the Rutherford Laboratory. The track enters from the left in both views, and the decay positron can be seen on the right. The increase in pulse height at the end of the muon track can also be seen. (Photo courtesy of the Rutherford-Appleton Laboratory.)

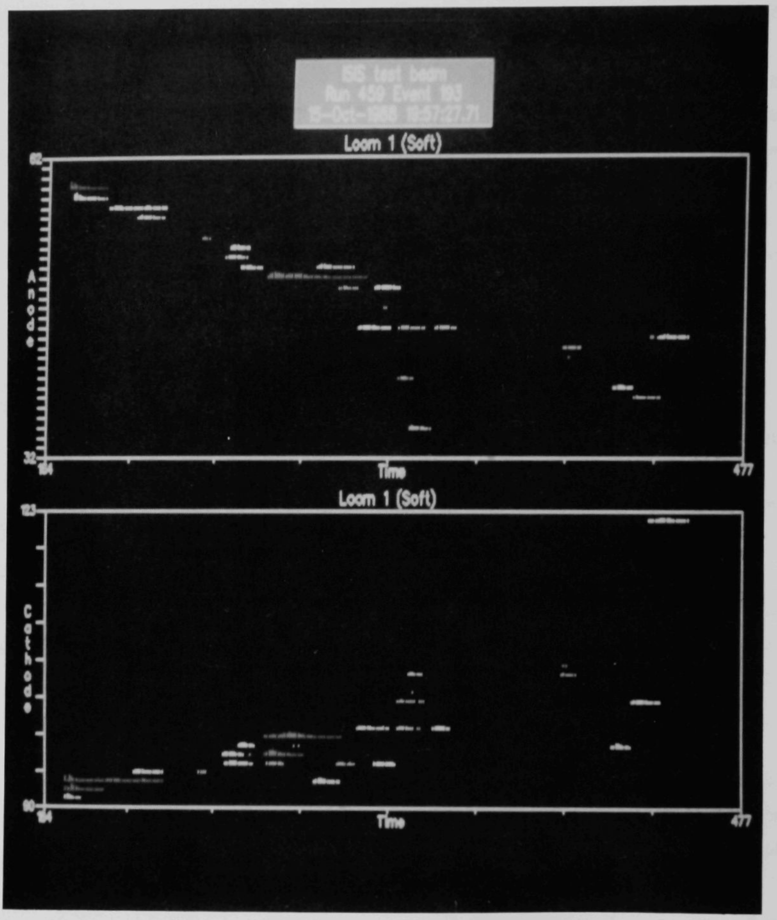


Fig. 12. Two orthogonal views of a 236 MeV/c electron shower in a Soudan 2 module in the ISIS test beam at the Rutherford Laboratory. The track enters from the left in both views, and the shower develops to the right. The individual pulses in the two views can be matched using their drift times (horizontal coordinate) and pulse heights. (Photo courtesy of the Rutherford-Appleton Laboratory.)

2. Fermilab Polarized Beam

Much of our effort in this period has been in the ongoing preparation for our next run which may begin in December. We also wrote a new version of our Fermilab proposal 678 for re-submission. Considerable effort has gone into preparing papers on the results of the polarimeter experiments from the last run and an extensive paper on the beamline for Physical Review.

Argonne has responsibilities in several areas for the four experiments, beam facility, polarized target, and polarimeters. The polarized target is to be used for about half of the 1990 run in the $\Delta\sigma_L$ experiment, also for a low intensity run measuring the A_{LL} parameter for pi-zero production in the central region, and a test of a direct photon experiment. It may be used for some time in the 1990 run for a a high intensity pi-zero run if the beam scheduling (sharing primary beam with the kaon beam) permits. It will be used for the high intensity running in the 1992 run. Preparations for the target are going fairly well except for delays which are partially due to a lack of people to do the safety documentation for Fermilab. The polarized target is reported on in detail elsewhere.

The smaller multi-wire proportional chambers, MWPC, have been assembled at Argonne and are being tested. The frames for the larger two meter chambers have been machined in the Argonne shops and assembled by the HEP technicians and physicists. The printed circuit boards have been prepared. These chambers will soon be wound at Fermilab. A contingency plan has been prepared for distributing the Pcos MWPC electronics in the optimal way for tracking since it unlikely that electronics will be available for every wire. Argonne is also preparing a large support system for the 2 two meter chambers, a hodoscope from Trieste for the Lambda trigger, and possibly a large drift chamber. It will be possible to slide each chamber or hodoscope out of the beam for repair.

Argonne and Northwestern people are working closely on the setup of the $\Delta\sigma_L$ experiment. This experiment may appear to be simple since it uses only scintillation hodoscopes for the actual data and the scalers are recorded, rather than individual events. However, approximately 172 phototubes are used, and many correlations must be formed in fast logic for every beam track. We use 60 ns memory look-up to get momentum in 14 bins, polarization in 13 bins, scattering angle in 16 bins in x and y, and momentum transfer,t, in 16 bins. We must then scale the combinations of t and polarization and do monitoring, accidentals subtraction, etc. There will be approximately 600 scaler channels. The on-line analysis is expected to find systematic problems and physics answers in almost real time. Theories which work at energies below 12 Gev predict asymmetries of ~ 10^{-5} with our beam and target parameters. There could be other contributions to the two spin asymmetry, $\Delta\sigma_L$, and there is a prediction, controversial, of a single spin, parity violating asymmetry of 10^{-4}. We are continuing our calculation of small spin components in the beam, transverse to the desired spin component, which could contribute to systematic errors. We are setting up the fast logic and writing the analysis program.

In light of the recent EMC results which indicate that much less than half a unit of angular momentum is carried by valence quarks in the proton there is considerable interest in measuring the contribution of gluons and strange quarks. One of the best ways to measure the gluon contribution is with a direct photon experiment utilizing polarized proton beam and target. The E704 beamline is unique facility of the type required for this experiment, and the detector using lead glass from Serpukhov is the type of detector required. Detailed Monte-Carlo studies have been undertaken to look in detail at what is required and an update to our previous proposal P678 to do such an experiment has been written. With an additional 1000 lead glass blocks which Serpukhov is willing to provide, and a simplified large area photon detector which Kyoto/KEK is willing to provide we could do well at detecting the direct photon signal with good efficiency and minimal background. An upgrade to the beamline would provide both more flux and a higher cross section at higher energy. At present we are submitting the proposal to run with the existing beamline. We are proposing to use polarized ^{6}LiD as a target to enhance the effective polarization. Tests of such a target are being discussed with LAMPF and Saclay.

(D. Underwood)

3. ZEUS Detector at HERA

In the first half of 1989 the production line for the 32 barrel calorimeter modules of the ZEUS detector was established. In addition, preparations for the test beam facility at Fermilab were begun. A summary of the progress of each of the collaborating US groups follows.

Argonne National Laboratory (M. Derrick)

Module Production

The design of the production modules was finalized in this period. Although very similar to the prototype, there are many small dimensional differences between the prototype and the production modules. With a few small exceptions, all of the mechanical components for the first six production modules are at Argonne. Production of the missing components is underway.

Stacking of the first production module is complete; the partially assembled hadronic section is shown in Fig. 13. As a result of this work, some small errors were discovered in the design of several parts which have now been corrected. Installation of the light guides and reflection masks will be done in mid-July. After this installation, the design of the light-tight module covers can be finalized. These covers are designed to hold the thin lead sheets that are needed between modules to ensure uniformity of response of the whole BCAL system in azimuth.

The uranium plates for module 2 are at Argonne, as are almost all of the plates for the EMC section of modules 3, 4, and 5. Delivery of the HAC plates for module 3 is promised by mid-July. Some difficulties are being experienced in obtaining satisfactory stainless steel skins needed to clad the HAC plates for modules 2 and beyond. Attempts are being made to ensure that the schedule will not be effected.

The procurement of a HAC stacking fixture and two module storage frames was initiated for Julich in this reporting period. These are duplicates of equipment already in use at ANL and are to be delivered to ANL for checkout in July, prior to dispatching them to Julich.

Fig. 13. Installation of scintillator panels in the HAC2 section of the first BCAL production module.

Cosmic Ray Tests

The Cosmic Ray Test Stand was completed in March. Studies of background levels for the drift tubes and trigger scintillation counters, once the prototype module was installed, required that they be shielded and that a third layer of trigger counters be installed in order to reduce accidental levels to a few percent. A substantial amount of cosmic ray data was accumulated with both the projective trigger to study the EMC tower response and the perpendicular trigger to study the HAC tower response. Early results for the HAC towers indicated the light yield was approximately as expected with about 3 photo electrons per layer per minion.

Magnetic Field Mapping

Preparations continued for the magnetic field survey of the ZEUS detector scheduled for August-September of this year. Our responsibility is to provide the field probes, based on the Hall Effect transistor, to measure the x, y and z field components at a matrix of points within the barrel calorimeter and also the VME based data acquisition system. The system will be installed at DESY over the period June to August.

The University of Iowa (U. Mallik)

The University of Iowa has major responsibilities in the area of software engineering for the Fermilab test beam setup which will calibrate and debug barrel calorimeter modules during the Fermilab fixed target run scheduled for January 1990.

The University of Iowa was responsible for buying and installing the complete test beam computer system at Fermilab. The T790 node FNZEUS with its software is now operational in the portakamp in lab E. The installations of the computer and the Fermilab user software were accomplished in coordination with Fermilab. We are also responsible for calibration and monitoring software, including online displays. This is anticipated to be the dress rehearsal for the ZEUS final software. Two summer students from the University of Iowa are presently working on the on-line displays. Having established the computer and the rudimentary software, we are now working on unpacking and interfacing data in the framework of the Fermilab software package VAXONLINE.

Nevis Laboratory (A. Caldwell)

Columbia is designing the analog and digital electronics for all of the high resolution calorimeter of ZEUS. We will only fabricate the electronics for the barrel part of the calorimeter and are working to the following schedule for this task in the first half of CY 1989.

Analog Card	
test prototypes	Jan-June 89
complete final card design	Jan 89
layout final card	Jan-Feb 89
construct 25 cards	Mar-June 89
design and layout controllers	Mar-June 89
start test of full system	June 89
order components for production	Jan-June 89
Digital Card	
complete design of card	April 89
complete layout of card	June 89
order components for prototypes	Jan-May 89

In addition, we have acquired a 2-transputer board and Caplin interface to set up a system resembling the final data acquisition system for use at FNAL and DESY. We have developed considerable software to systematically test and monitor the performance of the various electronics cards in the system.

Ohio State University (T. Y. Ling)

Responsibilities include the optical readout of the barrel calorimeter and the fast clear of the ZEUS trigger system.

Optical Readout for the Barrel Calorimeter

i) Status of Production

The production of scintillator tiles for the Barrel Calorimeter (BCAL) modules started in February. The scintillator tiles are laser cut by Laser Services Inc. of Mass., wrapped and scanned for nonuniformity at Ohio State and then shipped to ANL. Since the HAC and EMC scintillators are different in size, they are produced separately for each BCAL module.

HAC scintillators for the first BCAL module were completed and delivered to ANL in April. EMC scintillators for the first BCAL module were completed and delivered to ANL in May. In June, the production of HAC scintillators for the second BCAL module was completed. The HAC scintillator for Modules 3 and 4 have been laser-cut, wrapping and scanning is in progress.

The laser cutting of WLS-light guides for the first module was done in May. HAC light guides were all formed and scanned in June. Reflection masks for non-uniformity correction will be made before shipping to ANL.

EMC light guides for the first module were formed at Ohio State with LSU personnel participating in the work. The scanning and mask making plus source tube manufacturing will also be done at OSU. It is anticipated that all jigs and machinery for EMC light guides will be transferred to LSU so that they will be responsible for EMC light guide production starting with the second BCAL module.

ii) Source Scan of the BCAL Prototype Module

A preliminary scan with the CO^{60} source was done on the BCAL prototype module. The source scan system was developed and constructed at Ohio State. A 0.8 mc point source attached to the end of a piano wire is driven by a CAMAC controlled stepping motor down a 2 mm stainless steel guide tube positioned between every other EMC light guide.

The scan system was made operational in February and one third of the calorimeter towers were scanned in March. The data, when compared with EGS Monte Carlo simulation, show that the longitudinal uniformity is good to within 3% for HAC towers and 5% for EMC towers.

Fast Clear for ZEUS Trigger System

The raw interaction rate expected for ZEUS is on the order of 400 kHz, comprised almost entirely of beam gas interactions. This rate must be reduced to 1 kHz by the first level trigger. This is a formidable task since the first level trigger is pipelined. Every processing step in the first level trigger has to be repeated every 96 ns, which leaves no time for processes which require iteration.

The Fast Clear (FC) processor is designed to ensure that the effective readout rate for each detector component and the input rate to the second level trigger is ≤ 1 kHz. The Fast Clear processes each trigger issued by the Global First Level Trigger (GFLT) and issues a 'fast clear' request to the GFLT if it decides that a trigger is obviously due to beam gas interaction. The GFLT then sends an 'abort' signal to all components to abort reading out the event.

i) Status of the Design

The conceptual design of the FC system started about a year ago and is being finalized during this reporting period.

The FC is essentially a cluster finding processor. A cluster is a group of neighboring calorimeter super-towers which have energy depositions exceeding a pre-programmed threshold. The FC gets its input from the Calorimeter First Level Trigger. The digitized HAC and EMC energy values from each of the calorimeter components (FCAL, BCAL and RCAL) are processed in parallel and independently in its input crate. The data are then sent in parallel to the control crate where they are further processed. In this crate the data from the three calorimeter components is combined to form the trigger decision. The FC system is modular and is built with 7 types of cards. The design of several of these card types is in progress.

ii) Monte Carlo Simulations

During this reporting period, extensive Monte Carlo study was carried out to check the cluster searching algorithm and to investigate how to reject beam gas interactions and trigger on physics events with the highest possible efficiency. Monte Carlo events generated by Geant (version ZG311T5) were used as input to the program CLUST which simulated the FC cluster searching algorithm. A total of 5000 beam gas events, 500 weak charged current events and 300 weak neutral current events were used in this study.

The study shows that the FC cluster searching algorithm finds both hadron jet clusters and isolated electrons with very high efficiency and reproduces energies and angles of the jets and electrons well. Trigger algorithms and criteria are developed which are shown to reduce beam gas background by a factor of 400.

The speed of the FC processor depends on the clock rate and the necessary operations to be performed. The Monte Carlo study shows that the average processing time for beam gas events is about 20 μs.

The Virginia Polytechnic Institute (L. Mo)

Responsibilities include design and fabrication of the bases and high voltage (HV) distribution, monitoring for the photomultipliers of the ZEUS barrel calorimeter and development of DAQ on-line software.

Substantial time was expended by Bin Lu on trouble-shooting problems with the bases and HV system for the prototype module. This work has been documented in an AMZEUS note.

For the production modules, production of phototube bases has been delayed because of the late delivery of custom-made hybrid circuits.

Twenty new bases were manufactured with hybrid circuits and were tested. The noise level was found to be approximately 0.026 pC, which is slightly higher than that of the old bases, 0.02 pC. Improvement work is continuing. When these bases were installed on the prototype BCAL module at Argonne, an initial drift of high voltage of approximately 2 volts was noticed. The high voltage then stayed at a constant level. One plausible explanation, but without proof, is the radiation effect on the resistors.

Another 25 bases of the same type will be finished by July 15, 1989. In this total of 45 new bases, the hybrid circuits are a little bigger than desired. Corrections have been made. Two hundred new bases will be delivered on August 1, 1989. In order to reduce the damage caused by sparks, a one-meg-ohm resistor is inserted near the photo-cathode.

The delivery of the new high voltage controller, using an Ethernet communication system, is also delayed. The first unit will be completed by August 15, 1989.

University of Wisconsin (D. Reeder)

Calorimeter Activities

During the first half of 1989 the Wisconsin group has been concerned with a diversity of different activities and responsibilities. Our responsibilities include a wide range of mechanical aspects of the calorimeter modules and their installation procedures at both FNAL and DESY, together with photomultiplier testing and selection and design of the first level calorimeter trigger.

The design of the holey plates and magnetic shielding array was completed in this period and the acquisition of material and components began. The plates for the first two production modules have been delivered to Argonne and the delivery of three modules worth of partially completed plates for the magnetic field test at DESY were sent and are installed. Work is progressing in acquiring the parts for the photomultiplier caps and other ancillary equipment. (Loveless, Reeder, and Frankdowski). The final design of the cabling and cooling of the electronics is being negotiated with all members of the collaboration.

During this period the fixture for inserting the modules into the "spokesplate" was designed, built, tested at Argonne and sent to DESY where it was used to install the dummy "T" beams for the magnetic tests. (Reeder and Winch).

The testing of photomultipliers continues. (Kinnel and Loveless) The tubes are tested to determine the gain as a function of high voltage and to determine that the tubes satisfy the specifications concerning gain and dark current. The linearity is now also being tested. The testing procedure has been hampered by the delays in acquiring the new Cockroft Walton bases; however, we seem to be past this problem now.

Planning for the testing of the modules at FNAL involves the use of materials and space in the neutrino area at Labs E and F. The agreement with the collaboration and the laboratory was negotiated successfully by W. Smith.

The design of the several fixtures needed to store and manipulate the modules in the test beam at FNAL were completed in this period. Effort is now devoted to the acquisition of materials and the construction of the devices.

The UW group will also install and test the fixtures and their controls. (Winch and Reeder)

The software for the hardware control features of the online system is the responsibility of the UW group. (Loveless and Kehres) In addition J. Kehres serves as the systems programmer for the FNAL test computer system. The control system has been developed such that it can communicate with the other on board systems (transputers and 68,000 processors) and programs can be downloaded and data retrieved. Other projects related to Monte Carlo calculations and test beam reconstruction have been studied during this time.

Trigger Activities

The effort of the group during this period has focussed on finalizing the design of the trigger and beginning the layout on the new CAD/CAE facilities. The group has acquired two Apollo 4500 workstations, RACAL-REDAC Visula printed circuit board design, layout, and schematics software, and a Hewlett-Packard Wide Media pen-plotter. A member of our group, M. Jaworski, has been to several Visula training schools and has worked with a student (B. Thompson) in setting up the data base of devices necessary for the circuit designs. This is necessary because the design makes heavy use of state-of-the-art high speed CMOS, ECL, and integrated op-amps. The Apollo workstations were installed in January and the system has successfully produced its first cards, specialized bus terminator cards. Schematics for the design of the other cards in the system have already been entered.

The Wisconsin group has devoted considerable effort towards the completion of the design of the calorimeter trigger system. This design is scheduled for completion this summer. The conceptual, functional and system aspects are defined. W. Smith and J. Lackey (UW-PSL) have designs for the Trigger Encoder Cards, Adder Cards and Trigger Crates. The Trigger Encoder Card design is finalized and schematics exist. The Adder Card schematics are being worked on. Along with P. Robl (UW-PSL), they have designed the Trigger Sum Cards and analog signal processing and transmission. The cable connections and mechanical mounting in the calorimeter modules are being determined. M. Jaworski, with the help of B. Thompson is designing and laying out the printed circuit boards. (B. Musgrave)

II. THEORETICAL PROGRAM

Current theory research covers a broad spectrum of formal and phenomenological topics. These include: prompt photon production with polarized proton beams, heavy quark production, detection of a heavy Higgs boson, structure function issues including gluonic contributions to spin-dependent functions, single-spin production asymmetries, infinite dimensional algebras relevant to large N limits, stability of the vacuum in the standard model, the importance of confinement for the Pomeron in QCD, and the relevance of general relativity for phase transitions below the Planck scale. The following describes these activities in more detail.

Prompt Photon Production with Polarized Proton Beams

Ed Berger and Jianwei Qiu have calculated cross sections for inclusive direct photon production at large transverse momentum in proton-proton and proton-deuteron interactions. In Phys. Rev. D40, 778 (1989) and in Argonne report ANL-HEP-PR-88-68, submitted to Physical Review, they argue that inclusive direct photon production at large transverse momentum with longitudinally polarized beams and targets is an incisive probe of the polarized gluon density in a nucleon. To help motivate future experiments and assist in their design, they provide predictions of the polarization asymmetry for a range of reasonable choices of the polarized gluon density. The cross sections are small at fixed target energies, but the effort to measure them is necessary if the polarized gluon density $\Delta G(x,Q^2)$ is to be determined. In order to obtain their predictions, Berger and Qiu parametrize spin dependent parton densities and compute their evolution with Q^2. Their densities provide good agreement with the spin dependent structure function $g_1^p(x,Q^2)$ measured in deep inelastic lepton scattering. Measurements with polarized deuteron targets would take advantage of recent advances in the technology of polarized target materials.

Heavy Quark Production

Ed Berger prepared invited reviews of heavy quark production for delivery at two major conferences: the IX International Conference on Physics in Collisions, Jerusalem, June, 1989, and the Workshop on B Factories and Related Physics Issues, Blois, France, June, 1989. These invited reviews include a summary of Berger's computations of the cross sections for charm, bottom, and top quark production in $\bar{p}p$, π^-p, and pp interactions at fixed target and collider energies. The calculations are done through next-to-leading order in QCD perturbation theory. Predictions are presented for various measurements including expected quark-antiquark correlations. The sensitivity is explored of results to the choices of renormalization/evolution scale, parton densities, Λ_{QCD}, and heavy flavor masses. Comparisons with available data show that good agreement is obtained for reasonable values of charm and bottom quark masses and other parameters. Open issues in the interpretation of results are summarized including the large size of the next-to-leading order contributions, proper definition of the gluon density, the nuclear A-dependence of charm cross sections, the role of final state interactions, and higher twist effects.

A New Method to Detect a Heavy Top Quark at the Tevatron

In an ANL preprint ANL-HEP-PR-89-44, Chien-Peng Yuan has presented a new method to detect a heavy top quark with mass ~180 GeV at the upgraded Tevatron ($\sqrt{S}$ = 2 TeV and integrated luminosity 100 pb^{-1}) and SSC via the W-gluon fusion process. He shows that an almost perfect efficiency for "kinematic b-tagging" can be achieved due to the characteristic features of the transverse momentum and rapidity distributions of the spectator quark which emitted the virtual W. Hence, it is possible to reconstruct the invariant mass $M^{e\nu b}$ and see a sharp peak within a 5 GeV wide bin of the $M^{e\nu b}$ distribution. Yuan concludes that it is possible to detect a 180 GeV top quark at the upgraded Tevatron, and its detection becomes easier at the SSC due to larger event rate.

Reliability of Monte Carlo Simulations of Bottom Quark Production at Collider Energies

As an important part of their study of strategies for detection of the top quark, Ed Berger, C-P Yuan, David Kuebel, and Mark Pundurs have been assessing the extent to which existing Monte Carlo programs properly incorporate next-to-leading order contributions in QCD. These contributions are especially relevant for production of bottom and charm quarks at large values of transverse momentum. It is essential to model these contributions accurately since they constitute a major background in the search for top and other new physics. Large samples of events have been generated with the ISAJET Monte Carlo program, separated into lowest order and next-to-leading order subsamples, $O(\alpha_s^3)$. Comparison of these distributions with the results of a proper analytic calculation through $O(\alpha_s^3)$ shows fair agreement for the single quark momentum transfer distribution at both $\sqrt{s}$ = 630 GeV and $\sqrt{s}$ = 1.8 TeV. However, there are important discrepancies in the magnitude and momentum transfer dependence of the ratio of the $O(\alpha_s^3)$ and lowest order contributions. This discrepancy implies that ISAJET models the expected topology of events incorrectly, a serious drawback in that relatively too much background and incorrect final state correlations are generated. Theoretically motivated remedies are being investigated, and a paper is being prepared for publication.

Longitudinal W's in the TeV Region

Chien-Peng Yuan (in collaboration with Gordon Kane from the University of Michigan) has examined some new techniques to experimentally study interactions of longitudinal W bosons in the TeV region, and to detect a heavy Higgs boson (mass $\geq$1 TeV) if it exists. This is a problem that must be solved if we are eventually to fully understand and test how the $SU(2) \times U(1)$ symmetry of the Standard Model is broken. To do so at a hadron collider requires methods to discriminate against large backgrounds. Yuan and Kane use a new method based on the color properties of the signal and background, leading to a multiplicity cut, and they use analysis techniques that do not reduce the signal events by strong cuts. Their techniques do not bias W decay distributions and they conclude that it is possible to detect longitudinal W's even in the presence of background.

This work is described in the ANL preprint ANL-HEP-PR-89-43. Results are given for these matters at the SSC. The use of the "Equivalence Theorem" between longitudinal W's and Goldstone scalars is examined in several ways; in particular, it is emphasized that in practice the equivalence does not hold numerically when the widths of heavy resonances are included in the traditional way, i.e., using the Breit-Wigner prescription. The violations are numerically large.

Gauge Boson Couplings

Visitor Ulrich Baur from CERN and Ed Berger studied the coincidence reaction $\bar{p}p \rightarrow W\gamma X$ at collider energies. The anticipated $W\gamma$ event rates $\sqrt{s}$ = 1.8 TeV show that the CDF collaboration can make a valuable contribution to the study of triple gauge boson couplings and possible anomalies. A paper is being prepared.

Structure Functions and Parton Densities

As chairman of a Nuclear Science Advisory Committee working subgroup concerned with long range planning, Ed Berger prepared a report on desirable future experimental and theoretical studies of parton densities and structure functions of nucleons and nuclei. The report, issued as ANL-HEP-PR-89-76, examines open questions in deep inelastic lepton scattering, massive lepton pair production (the Drell-Yan process), and inclusive prompt photon production. A comprehensive program of new investigations is outlined in the report.

Gluonic Contributions to the Proton's Spin-dependent Structure Functions

Geoffrey Bodwin and Jianwei Qiu have investigated whether the first moment of the structure function $g_1(x)$, which appears in deep inelastic scattering of a lepton on a polarized proton, can receive contributions from the distribution of gluons in a proton. This work has been stimulated by the recent measurement of g_1 by the EMC collaboration and also by the interpretation of that result suggested by Altarelli and Ross (AR) and Carlitz, Collins, and Mueller (CCM). AR and CCM have proposed that the first moment of g_1 receives contributions from the gluon distribution as well as from the quark distributions in the proton. Bodwin and Qiu have investigated whether the suggestion of AR and CCM leads to a satisfactory definition of the spin-dependent distribution of quarks in the proton. The central issue is whether a process in which a gluon produces a q-$\bar{q}$ pair should be regarded as a contribution to the hard gluon-lepton cross section or as a contribution to the quark distribution function. Bodwin and Qiu have given a general argument which shows that the gluonic pair-production process does not lead to an additional hard gluonic contribution to the first moment of g_1, provided that one defines the quark distributions in a way that respects gauge invariance and the usual analyticity structure of the quark distributions. (This last assumption amounts to preserving the optical theorem at the parton level.) They have checked this general result through explicit calculations using dimensional and Pauli-Villars ultraviolet regulators and dimensional, quark-mass, and off-shell infrared regulators. Bodwin and Qiu have also found that if one is willing to give up the optical theorem at the level of the parton cross section, then it _is_ possible to define satisfactory quark distributions such that there is a hard gluonic contribution to g_1 of the type suggested by AR and CCM. This definition of the quark distributions has no analogue in terms of the operator product expansion because the moments of the distributions are bilocal rather than local operators. Consequently, one must take care in using these distributions, since the Bjorken sum rule no longer holds in the nonsinglet case.

Single-Spin Production Asymmetries

There have been several erroneous conclusions over the years concerning theoretical predictions for "single-spin" observables. It is frequently claimed that QCD requires such asymmetries to vanish at large transverse momentum like,

$$A = \alpha_s \frac{m_q}{\sqrt{s}} f(\theta) .$$

Dennis Sivers has refuted these claims with a simple counterexample using the QCD hard-scattering model. When one takes into account the transverse momenta of the constituents in a polarized proton or other hadron, there exists a kinematic, trigger-bias, effect in the formulation of the QCD-based hard-scattering model which can lead to larger single-spin asymmetries than previously supposed.

Sivers' picture is based on a natural space-time formulation and leads to the asymptotic behavior

$$A = \frac{c\langle k_T\rangle}{p_T}$$

where c is independent of the quark mass parameter and is not suppressed by a power of α_s.

SU(∞), SO(∞), Sp(∞), Hamiltonian Flows, and Strings

C. Zachos has continued the exploration of the infinite dimensional algebras he invented last year with D. Fairlie and P. Fletcher (University of Durham, UK), which include as a special case the Lie algebra of area-preserving-diffeomorphisms of the torus (it amounts to that of Poisson Brackets, i.e. generic hamiltonian flows). Another remarkable subfamily of these algebras contains SU(N) (and hence SO(N) and Sp(N)) as subalgebras. This led the above investigators to identify SU(∞) with the above Poisson Bracket algebra, by taking the infinite N limit [Phys. Lett. 224B (1989) 101]. Even though a particular instance of such a connection was already known to J. Hoppe for the sphere, the simplicity of this identification has already made it the standard in this area and has allowed complete and firm generalization. For example, it describes the infinite N limit of all classical Lie algebras in terms of canonical transformations on the torus driven by special hamiltonians. Moreover, it has occasioned a cogent, systematic, and unambiguous formulation of SU(∞) gauge theory in terms of a toroidal world-sheet of "color", which bears promise for phenomenologically relevant large N computations.

Perhaps more significantly, Zachos was thence led to identify a string action that emerges naturally out of the Yang-Mills Lagrangian. No such direct connection had ever been available, although indirect associations and tantalizing clues had been accumulating for a decade and a half. Even though the crucial distinguishing feature of particle physics is the nontrivial mathematical structure of its laws, the innovative mathematical tools required for their formulation are rarely developed by mathematicians. Authors who have been utilizing and extending the results mentioned include J. Hoppe; C. Pope; K. Stelle; L. Romans; B. de Wit; H. Nicolai; I. Bakas; E. Floratos; P. Sorba; M. Saveliev; R. Schrock; U. Marquard; and others.

The Stability of the Vacuum

The electroweak vacuum need not be absolutely stable. For certain top and Higgs masses in the minimal standard model, the vacuum is instead metastable with a lifetime exceeding the present age of the universe. Some have suggested that a metastable vacuum is generally ruled out because high-energy cosmic ray collisions would have long ago induced its decay. In his paper "Can the Electroweak Vacuum be Unstable?" Peter Arnold has shown that this conclusion is erroneous and that, in consequence, upper bounds on the top mass derived from stability arguments are relaxed.

Confinement and the Pomeron

In a paper prepared for the Northwestern Conference on Elastic and Diffractive Scattering, Alan White discusses the importance of confinement for obtaining a unitary high-energy limit for QCD. After reviewing the relevant results from leading and non-leading log calculations White argues that minijet contributions--calculated using a lower transverse momentum cut-off build up non-unitary high-energy behavior. He then argues that for minijets to mix with low transverse momentum Pomeron Field Theory describing confinement and give asymptotic behavior consistent with unitarity, new "quarks" (probably in a higher color representation) must enter the theory above the minijet transverse momentum scale. The Critical Pomeron is the resulting high-energy limit.

General Relativity and Early Universe Phase-Transitions

Peter Arnold has been studying the effect of general relativity on first-order phase transitions in the early universe. One would initially expect that general relativity should play an insignificant role in the rate of phase transitions for physics substantially below the Plank scale, such as the QCD and Weinberg-Salam phase transitions. Surprisingly, Berezin, Kuzmin and Tkachev found a new type of tunneling solution where general relativistic effects seem to play a crucial role and substantially modify phase-transition rates. Arnold has found, however, that these solutions are not, in fact, relevant to the problem of phase transitions; the expectation that general relativity is insignificant remains valid. An extension of the analysis used for this problem can also be used to study the effect of black holes on phase transition rates, which is work that Arnold is currently concluding.

III. EXPERIMENTAL FACILITIES RESEARCH

A. Mechanical Support

Proton Decay

Module construction continued at a decreased rate due to problems encountered with outgassing of unknown compounds which poison the gas in the modules. After analysis it was determined that the problem was originating in the polystyrene inserts. This was thoroughly investigated and a signficant number of polystyrene inserts were declared unusable. New inserts that did not demonstrate the outgassing were ordered based on samples furnished by the vendor.

New material with less intrinsic radiation was ordered and incorporated into the wire plane cathode boards. A continuous program to improve the efficiency of module assembly has been successful in increasing the rate that modules can be constructed.

ZEUS Detector at HERA

All of the U.S. fabricated module frames were received from the supplier and inspected. The dummy module frames fabricated in West Germany (Hans Schlock, Osnabrook) were received by DESY and assembled into the barrel in preparation for magnetic field mapping.

The first production module was completed during this report period and the second module was started.

Design work has continued on the support system for shipping modules overseas. This system has been designed to protect the module from vibration and shock loading in excess of 5 g (see attached Fig. 14).

Collider Detector at Fermilab

R&D efforts continued on preradiators for the electromagnetic calorimetry. A series of mini chambers $2\frac{1}{2}$" x 5" were constructed to determine construction parameters for full size chambers.

Radioactive source and cosmic ray testing of the minichambers was conducted at Argonne. Tooling and construction techniques were developed for construction of full size chambers, see Fig. 15.

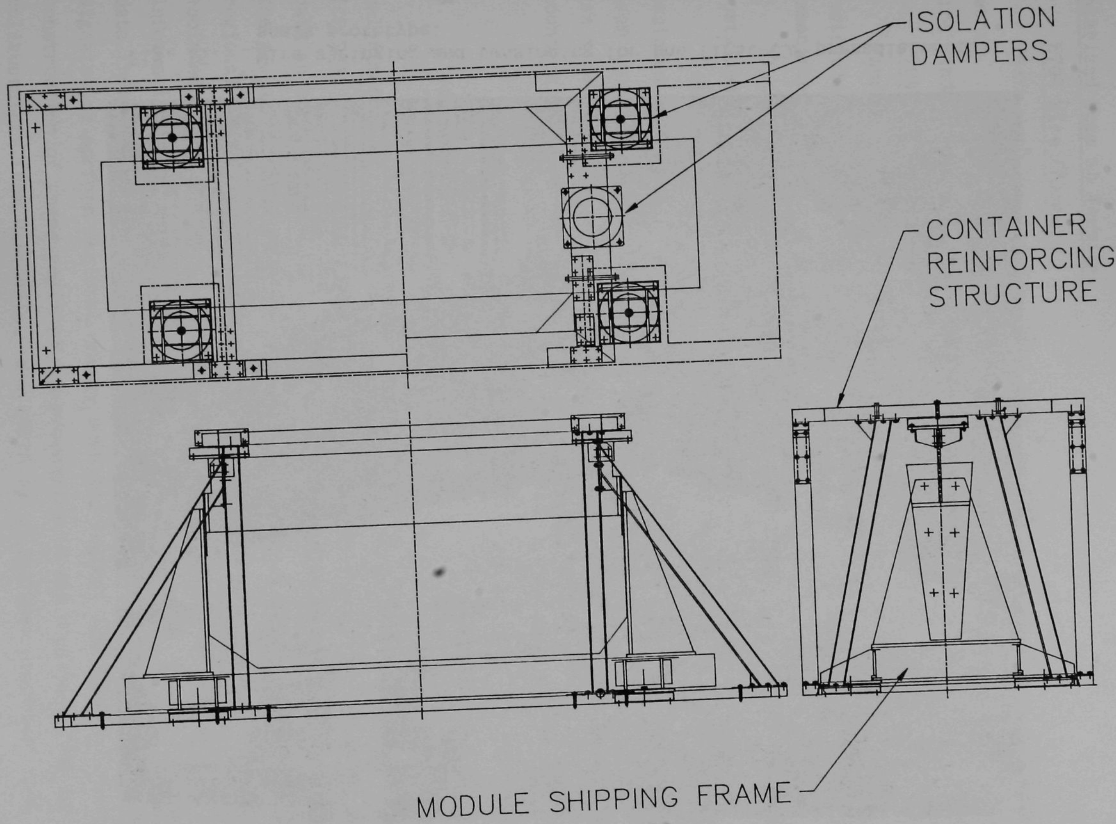


Fig. 14. Module shipping structure as assembled in the shipping container.

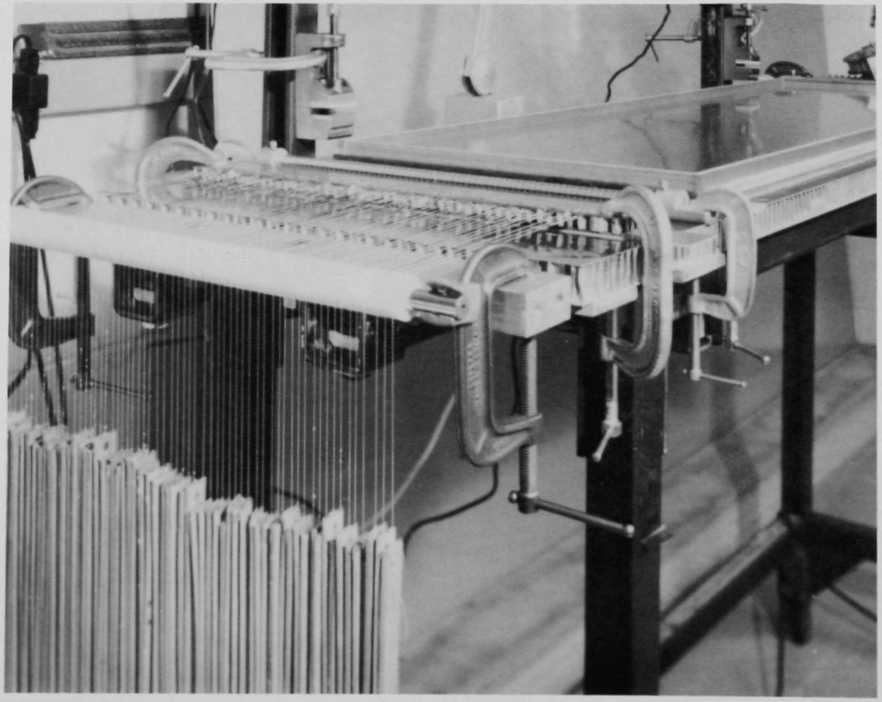


Fig. 15. Wire stringing and tensioning for the first CDF preradiator full scale prototype.

Polarized Beam at Fermilab

E704 Wire Chambers

Tests were completed on PC12 left and PC12 right, PC3 was assembled and tested. PC4 was assembled and is ready for testing. PC8 & 9 are ready for wire winding. PC10 prime is currently being revised.

E704 Polarized Target

Fabrication and installation of various components for the helium 3 recirculating system were completed, and the liquid helium 4 dewars and their associated plumbing and level controls were installed.

Plumbing and vacuum system for the superconducting solenoid were also installed during this period.

A wire extruder for making indium seals for the dilution refrigerator was designed and built. The dilution refrigerator and solenoid were aligned to beam line. Safety analysis is being done on all target components (dewars, gas recovery systems, etc.). A support frame for supporting wire chambers and counters was designed, constructed and installed. (N. Hill)

B. Electronics Support

Our major effort during this period with regard to support of the ZEUS calorimeter was in the design of the first level calorimeter trigger processor (CFLTP). The ZEUS calorimeter first-level trigger processor presents summary data on energy deposition in the uranium/scintillator sampling calorimeter to the global first-level trigger (GFLT). The summary data includes global and regional sums of electromagnetic and hadronic energy deposition, the number of isolated muons and isolated electrons, missing transverse energy, jet cluster information, and the likelihood of beam-gas background. The CFLTP receives data from 16 regional trigger pre-processors which digitize the calorimeter signals and perform regional energy sums and logical operations. Design and construction of these regional pre-processors is the responsibility of our collaborators from Wisconsin. The CFLTP is a pipelined processor that contains data from a number of crossing periods at any instant. It can capture input and output data from a sequence of up to 4096 consecutive beam crossings or first-level trigger events for detailed examination. All data variables are accessible for histogramming; the histograms are evaluated by 88000 RISC processors that reside in VME buses, embedded within the CFLTP. Input or output data emulation capability is provided to operate the CFLTP at full speed in a stand-alone mode. In addition, the design includes a number of utility functions to inspect the data flow and to assist in troubleshooting.

The ZEUS experiment at the HERA colliding electron-proton facility uses a sampling calorimeter with uranium as the showering medium interleaved with strips of plastic scintillator for energy sampling. It is designed to produce equivalent output for hadrons and electrons of identical energy. The calorimeter is divided into three sections: the barrel (BCAL), front (FCAL), and rear (RCAL). The inner portion of the calorimeter is called the EMC and detects mostly electromagnetic showers. The outer portion(s) detect mostly hadronic showers (HAC). BCAL is composed of 32 wedge-shaped azimuthal modules. FCAL and RCAL are planar and composed of 23 vertical modules. The EMC section is finely segmented, with a typical arrangement of four EMC towers in front of a HAC tower. (Typically BCAL and FCAL have two stacks of HAC behind the EMCs; RCAL has one HAC stack behind the EMCs). The BCAL EMCs are segmented (53 segments) in projective tower geometry. The 14 HAC towers are non-projective and are aligned perpendicular to the beam direction. The F/RCAL EMCs and HACs are non-projective and are aligned along the beam direction. Typically there are four EMCs in front of every HAC in FCAL and BCAL and there are two EMCs in front of every HAC in RCAL. The calorimeter is described by "regions" and "supertowers" (ST) for the first-level calorimeter trigger. Typically, each region consists of 56 ST. The definition of an ST will vary depending on location in the calorimeter. The simplest definitions are near the beam pipe for F/RCAL and at 90 degrees from the interaction region for the BCAL. In those places, an FCAL or BCAL ST consists of four EMC towers and the HAC towers directly behind them; an RCAL ST consists of two EMC towers and one HAC tower. The most complex definitions of STs are near the periphery of F/RCAL and at the boundaries of BCAL with FCAL and RCAL. There are 16 regions of the calorimeter: the four quadrants of FCAL, four quadrants of RCAL, four 90 degree azimuthal sections of the front half and four sections of the rear half of the BCAL. Every 96 nsec the electron and proton beams cross in the interaction region of ZEUS. Scintillation light produced in the calorimeter is extracted by means of wavelength-shifter guides and presented to photomultiplier tubes (PMT). The first-level trigger system receives 5% of the current produced in every PMT. The currents are routed from the "analog DAQ cards" to "trigger sum cards" (TSC), located on the calorimeter backing, to produce analog sums for EMC and HAC supertowers. The analog outputs from the TSC are transmitted over 60 m of cable to the electronics room for digital processing. The HAC and EMC signals for each ST are digitized and pre-processed by trigger encoder cards and adder cards that reside in customized VME crates. [Ref. W.H.Smith et al., ZEUS Note 89-085]. Each VME crate contains 14 custom-made trigger encoder cards and 2 adder cards for pre-processing data of one calorimeter region. It performs three basic functions on the digitized data, yielding regional pre-processed data which is transmitted to the CFLTP. The functions of one custom VME crate are outlined below.

a) The regional values of energy (E), transverse energy (Et), x-energy (Ex), and y-energy (Ey) are summed for EMC and HAC separately.

b) The energy of each ST is compared to 6 different (and programmable) threshold windows. The number of STs in a given energy window is determined for the entire region as well as for eight subsets of the region. In this way a crude determination of energy deposited in certain (programmable) portions of a calorimeter region is made. A region edge is one portion of particular interest.

c) The energy in each ST is tested to determine if it is predominantly electromagnetic. Also the energy in each ST is tested to determine if it is consistent with that deposited by a minimum-ionizing particle. The STs in the immediate vicinity are tested to see whether the above-mentioned energy deposits are isolated. If so, the energy is presumed to have been deposited by isolated "electrons" (or photons) and isolated "muons". The number of isolated "electrons" and isolated muons contained in each region is reported. Potentially isolated energy deposits along the edge of a region and the position of the edge are reported so that the CFLTP can determine whether energy isolation is consistent with energy deposition on the edge of the neighboring region.

The CFLTP receives 64 words (16 bits/word) of data from the regional adder cards every 24 ns for processing. It also receives control and status data every 96 ns from the GFLT and distributes GFLT control informtion to the pre-processors. The CFLTP can capture any particular set of input and output data upon software or hardware command, up to a total corresponding to 4096 beam crossings. This includes data from a beam crossing that resulted in a first level trigger (GFLT "ACCEPT"). Captured data are available via VME to the Motorola 88000 microcomputers that reside within the CFLTP. The CFLTP maintains histograms of input and output variables. Histograms are evaluated periodically by on-board microcomputers. Data that falls outside predetermined bounds of a histogram is reported to the calorimeter equipment computer and to the DAQ computer via VME. In addition, the CFLTP can emulate input or output data for 4096 consecutive beam crossings. Emulated data is programmable or may consist of previously-stored (real) data. Emulated data is available on the input cards or on the output cards of the CFLTP via software-controlled switches. The processed summary data consists of 32 words output at 96 ns. It includes the following information.

a. Global hadronic and electromagnetic energy deposition: scalar sum of energy, energy flow transverse to the beam direction, vector sum of transverse energy (missing energy).

b. The number of isolated electrons and isolated muons.

c. The likelihood of jet clusters.

d. The likelihood of beam-gas interaction.

e. Regional information on energy and transverse energy deposition, the number of isolated muons and electrons, and the likelihood of jets.

f. The error status of adder cards, CFLTP, and calorimeter DAQ.

The data from the adder cards is clocked at 24 ns to the CFLTP. Upon arrival, the data is latched, de-multiplexed and processed. The processor unit forms global and regional sums and logical operations as stated previously. Data from the CFLTP inputs is routed via high density connectors to a multilayer processor backplane. After a number of summing and/or logical operations, the data are fully processed. Either the actual processed data or emulated data (stored in FIFOs located on one of the processor unit's cards) as determined by software is routed from the processor backplane to the CFLTP output. Data can be captured and transported to VME for detailed inspection. Two types of data capture are possible. The first type captures input and output data that correspond to beam crossing that resulted in a GFLT. This will happen with an aprroximate rate of 1000 Hz. The second type captures input and output data for 4096 beam crossings at a time. These crossings may be consecutive, in which case the captured data corresponds to 384 microseconds of real time. Input or output data can be simulated by loading data patterns under software control. The patterns are downloaded from VME to 4096-deep FIFOs and stored. On software command, the buffers feed data into the input or the output of the CFLTP at full speed. The FIFOs may be loaded either with software-generated data or with previously-captured data. Histograms are derived from data contained in FIFOs at the CFLTP input and output, and are formed by resident microprocessors in VME. Current histograms are compared to standard benchmark histograms, and significant deviations are reported to the equipment computer. Design is proceeding on the CFLTP and subsets of hardware are expected to be in operation at the test beam at FNAL in January 1990, with the finished system ready for installation at HERA in early fall 1990.

During the period, a continuing area of effort involved development of data acquisition electronics to support our development of the ZEUS Calorimeter. The CAMAC multiplexer which was developed for the HRS cryogenic system was redesigned with a large number of enhancements to function in a VME environment. This module is being used for mapping the magnet and acquiring data for the slow control in ZEUS. We produced a run of 30 of these modules to support the FCAL tests at CERN, the magnet mapping at DESY, and our collaborators efforts in general.

In addition, of course, work continued to support the nucleon decay experiment, Soudan 2. Our involvment has become one primarily of construction and maintenance. During the period we performed the following tasks:

PDK Tasks Accomplished - January 1-June 30, 1989

Fabricated and tested:

42 Cathode Receive AMPS
180 Anode Receive AMPS
32 Analog Cards
2 Gas Overpressure Protection Control Boxes
1 Compactor Set
18 Edge Trigger Cards [New Style- Surface Mount/Plds]
4 CAMAC Serial Highway Bypass Modules
5 CAMAC Interface Modules
4 Complete Data Crate Racks Including 8 Multibus Crates, 8 Receive AMP Crates, With Backplanes, Fans, Power Supplies, Wiring, etc..
1 Wire Plane Test Fixture Electronics
160 Pre-amp Modules
243 Active Summer Cards
2 Anode H.V. Distribution Boxes With the New DC-DC Converters
3 Drift H.V. Distribution Boxes
2 Wire Plane Continuity Checkers

Modified and Tested:

2 Anode H.V. Distribution Boxes- DC-DC Converter Mod.
6 Bertan H.V. Power Supplies- Connector Mod.
150 Anode Receive Amps- Mod to Cathodes
40 Analog Cards - Low Noise Mod
4 Data Crate CPU Cards- Set up for use at mine.

Miscellaneous:
Repaired existing electronics as necessary.
Ordered parts and equipment as required.

(J. Dawson)

C. Computer Support

The jobs completed by the Computer Support group during the first half of this year were to install several large software packages on Argonne systems, to provide system and application programming support on the ZEUS cosmic ray stand data acquisition system and to work with procurement on the purchase of the MicroVAX cluster system.

An updated version of the CERN program library was installed on both the VAX/VMS systems and the CRAY UNICOS system at Argonne. The GEANT library was included as part of this installation. Also the Unified Graphics system was updated with the addition of several device drivers. The ADAMO data management system was also installed.

Approval was obtained for the acquisition of a MicroVAX cluster to replace the 11/7xx series. Working with the Procurement division, the Requests for Proposals were issued and vendors have been selected.

In support of the ZEUS cosmic ray test stand effort, several programs were written for readout of uranium current. These programs were used to set the phototube high voltage in order to obtain uniform current and also to provide data for the cobalt source scan. The energy reconstruction algorithm was implemented on the fast Digital Signal Processors providing some online filtering of cosmic ray data. Finally, the data logging system was extended to include direct logging to 8 mm video cassette tape. (J. Schlereth)

D. Polarized Target Development

During the first half of 1989, our efforts were devoted entirely to the installation of the E-704 target at Fermilab. The following sections detail the work on each sub-system or major activity.

<u>^{3}He Recirculation System</u>

The system piping was completed, including the piping for the emergency pump system, fabrication and installation of the dust filter, and purchase and installation of the additional relief valves required by Fermilab. Final leak-checking of the system was begun. The flowmeters were calibrated. The electrical and pneumatic controls of the emergency pump system were finished. The main ^{3}He pumps were charged with oil.

<u>Liquid Helium Dewars</u>

The rupture disc assemblies were purchased and installed. The dewar insert and valve assemblies were fabricated and installed in all three dewars. The guides, rails, and stop were installed for the DR service dewar. The liquid helium level probes were wired. Work on the gas collection piping was begun.

Polarizing Solenoid

The rupture disc assembly was purchased and installed. The auxiliary wiring and modifications of the main power supply were completed. The insulating vacuum pumps were mounted and plumbed.

NMR System

The PDP 11/23 system was arranged in a single rack and the module wiring was restored. A new digital radio frequency source was ordered. Three NMR detector modules were built and tested.

Special Instruments and Techniques

The system monitor computer was purchased and installed. The residual gas analyzer arrived, was tested, and mounted on a cart. Special plumbing was made for RGA system tests. We designed and machined a wire extruder for making fresh indium cryogenic seals in the Dilution Refrigerator. We learned some CAD techniques for PC-board design and layout.

Safety

Several reviews by the Fermilab Cryo Safety panel took place during this period. This documentation for the helium dewars and Solenoid was completed and approved, and those items were approved for use. Engineering Notes were prepared for the analysis of the pressure safety of the ^{3}He Recirculation System, and submitted for review. One of the system components, an oil clean-up device, was rejected by Fermilab, and we began a market search for an acceptable replacement. At the end of this period it was becoming apparent that Fermilab's appetite for safety documents is threatening to exceed our resources for producing them.

Miscellaneous

The Dilution Refrigerator and Solenoid were aligned with each other and with the beamline, and the pump-tee flanges were aligned with the DR. Loading of the instrumentation and control racks was begun, as was the preparation and pulling of the associated cabling. (D. Hill)

IV. ACCELERATOR RESEARCH AND DEVELOPMENT

A. Advanced Accelerator Test Facility

The main emphasis of the AATF experimental program during this period involved the direct observation of plasma focussing. This work is of interest insofar as plasmas lenses have been proposed as final focus optical elements for linear colliders. Drive beam self-focussing had been inferred from our previous plasma wakefield measurements, where the nonlinear behavior of the plasma waves was explicable by assuming that the drive beam was self-pinched down to a significant fraction of the background plasma density. It was nevertheless desirable to measure the effect directly, and a technique was devised to diagnose the time structure of the beam profile as it exited the plasma.

The experiment involved placing a gas Cherenkov cell immediately downstream of the plasma source. Cherenkov light produced by the beam was then transported to the streak camera. Measurements were taken for different plasma densities and for the case of no plasma. Fig. 16 shows beam profiles for plasma on and plasma off cases. The focussing effect of the the plasma is unambiguous, and agrees well with the nonlinear plasma wakefield results.

Argonne Wakefield Accelerator (AWA).

The maturation of wakefield technology is exemplified by the success of the AATF program. It is now apparent that the appropriate next steps are demonstration of high gradient (> 100 MeV/m) wakefield acceleration and development of components necessary for a wakefield based linear accelerator. A major portion of the group's activities have been centered on the design and preparation of a proposal for a new experimental facility which will eventually include a 1 GeV wakefield accelerator, the AWA.

The AWA consists of a novel high-current laser photocathode rf gun, 10 MeV standing wave preaccelerator, and three travelling wave linac sections, which provide 100 nC, 10 ps electron bunches at 150 MeV to drive dielectric wakefield accelerator sections. The dielectric sections will yield gradients in excess of 100 MV/m, with an effective transformer ratio of 6 being attained by staging of multiple drive bunches.

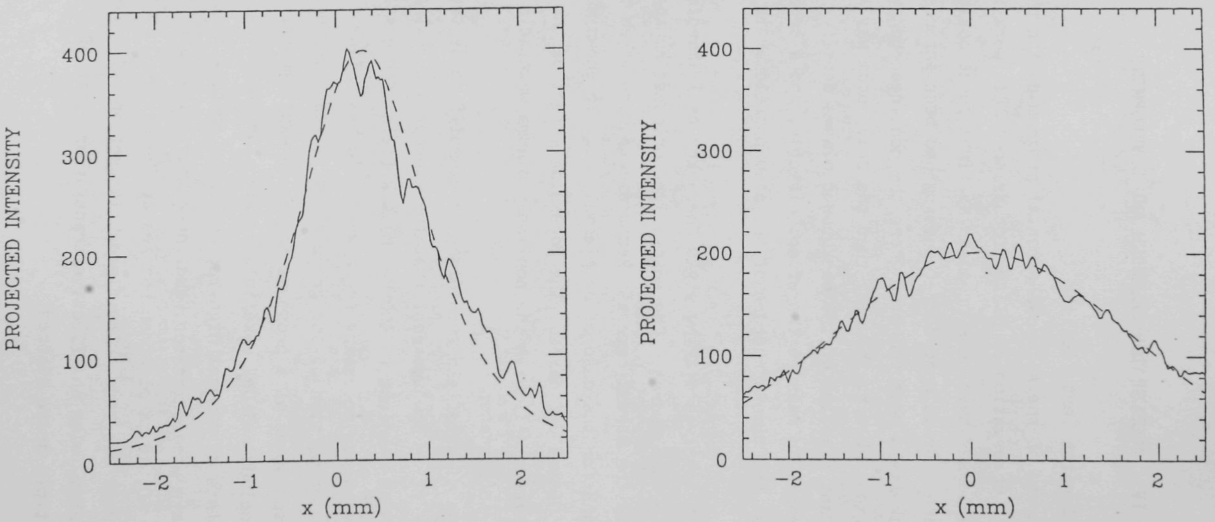


Fig. 16. Plasma on (a) and off (b) beam profiles (solid lines) demonstrating the plasma focussing effect. (Broken lines are fits to theoretical models.)

In addition to providing a practical demonstration of wakefield acceleration, the high intensity short bunches produced by the AWA drive linac will be utilized in the ongoing program of plasma wakefield and focussing studies. These experiments, and others which do not require the full 150 MeV beam energy, can begin as soon as the gun and preaccelerator are completed.

The gun design is essentially complete, having been presented to the DOE in November of last year as part of a proposal to upgrade the existing CHM linac. Construction of a prototype gun cavity was begun for low level rf testing. The preaccelerator design is also nearing completion, consisting of a conventional iris-loaded standing wave linac section with large apertures to minimize parasitic wakefields.

Work on the main drive linac sections is also proceeding. These will most likely use large aperture cavities like the preaccelerator, but will use an unusual ring resonator scheme to recirculate the rf through the cavity, thereby increasing the effective shunt impedance and reducing the rf power requirements.

A base design for beam optics and staging in the wakefield accelerator proper has been completed, as well as specifications for the laser and optical systems. The proposal will be sent to the DOE for review in July, 1989.

Computational Accelerator Physics

Work continued on the ARRAKIS code, which was developed to simulate dielectric-loaded accelerating structures. Both beam and rf driven devices (Fig. 17) may now be modeled. Efforts also included parallelization of the code to run on the machines at the ANL Advanced Computing Research Facility. Work began in conjunction with the ACRF on visualization of fields in these structures. (P. Schoessow)

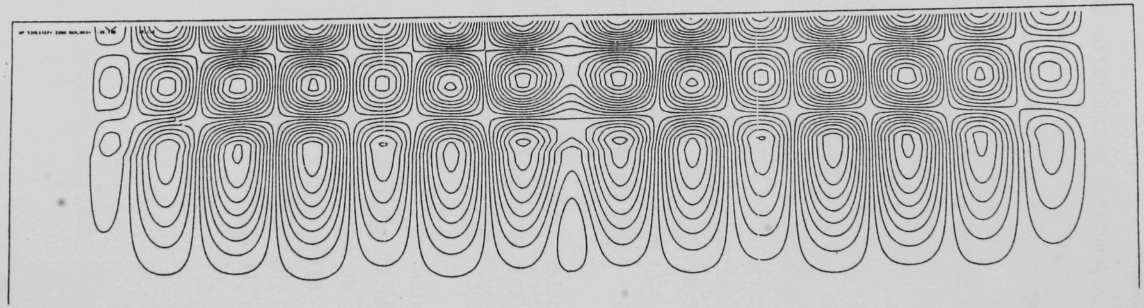


Fig. 17. Electric field contours for a 20 GHz RF-driven dielectric structure, computed using ARRAKIS.

V. SSC DETECTOR RESEARCH AND DEVELOPMENT

A. Detector Simulation Software for the SSC

While work continued on the fast shower algorithm for GEANT3 being developed at ANL, a series of calculations using full simulation was begun. Principally EGS4 and GEANT3 with the GHEISHA hadronic shower option were employed.

These calculations were aimed first at verification of the codes. For this purpose, calculations were made to reproduce test beam results. Both of the codes, but particularly GHEISHA, have several parameters such as energy cutoffs that must be set to compromise between execution time and precision. After a study to determine the best settings of the parameters, it was possible to obtain reasonable agreement with the longitudinal and lateral profiles of test beam data for both electromagnetic and hadronic showers (see Fig. 18). Resolutions could be reproduced well for electromagnetic showers, but the agreement of simulated and measured resolutions for hadronic showers was only qualitative. This is being studied.

A comparison was also made of the electromagnetic codes in EGS4 and GEANT3 (GHEISHA). As others had previously found, the two codes agreed quite well (see Fig. 19).

The comparison of full simulation calculations with test beam results will continue as more test beam results become available. Relatively few results have been published with detailed shower profiles, but efforts are underway to obtain measurements made for several experiments.

For the fast simulation, the major effort was on improving the precision of integration, both for obtaining the vector fields that are used in the two-dimensional integration method, and on the two-dimensional integration itself.

Simulation was a focus of the workshop on calorimetry held in Tuscaloosa in April. L. Price co-led the working group on simulation and chaired the town meeting on future directions for the subject. A major outcome of that discussion was the plan for a distribution center for simulation software. A proposal is being prepared for such a center to be located at ANL.

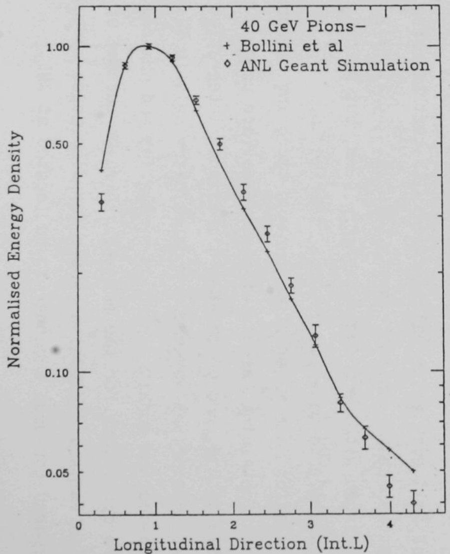


Fig. 18. GEANT3/GHEISHA simulations of hadronic showers compared with test beam calorimeter data.

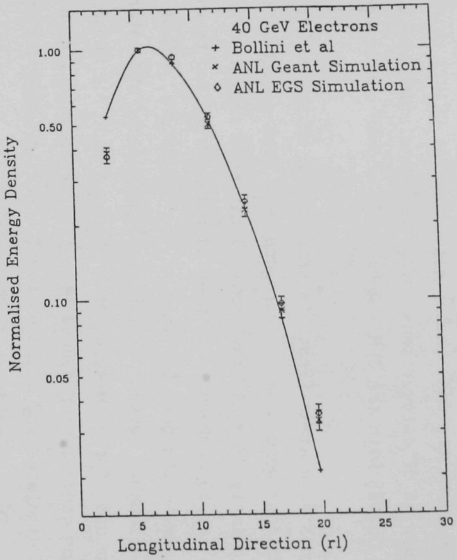


Fig. 19. GEANT3 and EGS4 simulations of electromagnetic showers are compared with test beam calorimeter data. The two simulations agree well and match the data except in the tail.

SSC Detector Design

A new activity was begun aimed at the design and eventual construction of a detector for the Supercollider. Many Argonne people have participated in the numerous summer studies and other workshops doing planning for the SSC, but a more continuous activity is needed with the formation of the laboratory and the call for Letters of Intent in May 1990.

A start was made on collaborative work on detector design with a one-day workshop at Argonne on May 8. About 50 people attended from 12 universities in addition to Argonne. The meeting was organized around talks on what is needed for SSC detectors and suggested ways to realize the required capabilities with time for group discussions on whether to begin a design study and how to organize it.

With general agreement that it was time to begin such an effort, a 2-day meeting was set for June 12 and 13, also at ANL.

This second meeting was organized with a few additional talks, but most of the time was spent in working groups on the various subsystems of a detector and on physics benchmark processes. About 12 additional universities and labs were represented at this meeting, with a total of 60 people attending.

The group decided to focus on a detector with scintillating plate calorimetry, scintillating fiber tracking, and a coil totally inside the calorimeter ("ZEUS type"). An integration group was established to suggest a complete detector model at the time of the next meeting, which was set for July 13 and 14. In discussions, it was decided to style this effort as a design study but not yet a collaboration. Thus it is still a somewhat informal organization that nevertheless can bring more concentrated study to the problem that have summer studies. (L. Price)

B. Superconducting Strip Detector R&D

During the first half of 1989 our study of switching in thin film superconducting strips moved on to using aluminum rather than niobium as a detection medium. Our previous work with niobium has demonstrated its sensitivity to 6 keV x-rays from ^{55}Fe using strips of submicron width. The energy deposited in the strip by absorption of these x-rays is approximately five times that from a minimum ionizing charged particle. Attempts to observe switching in niobium induced by electrons from a ^{90}Sr beta source have been unsuccessful. We have hypothesized that the combination of the large temperature difference between the liquid helium bath (4.2K) and the T_c of niobium (9K), and the relatively high specific heat of the niobium strip at 4.2K prevented formation of a hot spot of sufficient radius to drive the strip cross section normal when a minimum ionizing electron traversed it. For this reason, we chose to continue our studies with aluminum, whose critical temperature is in the 1.0 - 1.5K range. This temperature regime has the advantage that the specific heat of most materials is extremely small and the aluminum can be held at a bath temperature very close to its critical temperature. Particles traversing the strip will produce a much larger radius hot spot than in the case of niobium. This, in turn, allows use of wider strips that are much less sensitive to geometrical effects.

Aluminum strips of 2 μm width and 0.4 μm thickness have been fabricated at Argonne using a mask produced by our collaborator Ron Ono at the National Institute of Standards and Technology. The strip pattern was developed on a photoresist layer laid on a sapphire substrate. The aluminum film was then deposited on the substrate by evaporation. Finally, the photoresist and the aluminum deposited on it was removed, leaving only the desired strip pattern. The uniformity of the strips was studied by a measurement of the dependence of the critical current on the temperature at which the strip was operated, and found to be very good. The strips were subsequently irradiated with both an ^{55}Fe and a ^{90}Sr source in an attempt to observe superconducting-to-normal switching induced by the absorption of an x-ray or passage of an electron.

The first aluminum strips produced were essentially pure materials. The normal state resistivity just above the critical temperature was found to be too small to produce a propagating normal region. Thus, voltage pulses developed via the bias current through the normal region produced by the interacting particles were too small to be reliably detected above the ambient noise level. To remedy this situation the aluminum was evaporated in the presence of a small partial pressure of oxygen, producing a film of granular aluminum with relatively high resistivity and a critical temperature of approximately 1.5K.

A study of the switching ability of the granular aluminum films has recently been completed. A test strip was exposed to 6 keV x-rays from the ^{55}Fe source and the switching rate was measured as a function of the ratio of the bias current to the critical current. The results for two different bath temperatures are shown in Fig. 20. A plateau in the switching rate is seen to develop for $I/I_c > 0.6 - 0.7$. This would indicate that the strip becomes essentially 100% efficient above this bias current. A calculated estimate of the expected rate indicates an observed efficiency of 80%. The strip was then exposed to electrons from the ^{90}Sr source. The count rate as a function of the bias-to-critical current ratio for three bath temperatures is shown in Fig. 21. While a plateau similar to that observed for x-ray irradiation is not present, we have recorded for the first time, superconducting-to-normal switching induced by near minimum ionizing electrons. An estimate of the detection efficiency of the strip for minimum ionizing particles is complicated by the fact that the beta source does not provide a monoenergetic electron beam, but rather a spectrum of energies ranging from 0 - 2.2 MeV. Thus, there exists a contribution to the switching rate from electrons below about 0.5 MeV that deposit energy at a rate far above minimum ionizing. In order to conduct a clean test of the sensitivity of the granular aluminum strip to minimum ionizing particles, we plan to expose the strip to monoenergetic hadrons in a high energy accelerator test beam. This should provide us an unequivocal test of the ability of superconducting thin films strips to detect minimum ionizing particles and, thus, of the medium's ability to function as a tracking detector. (R. Wagner)

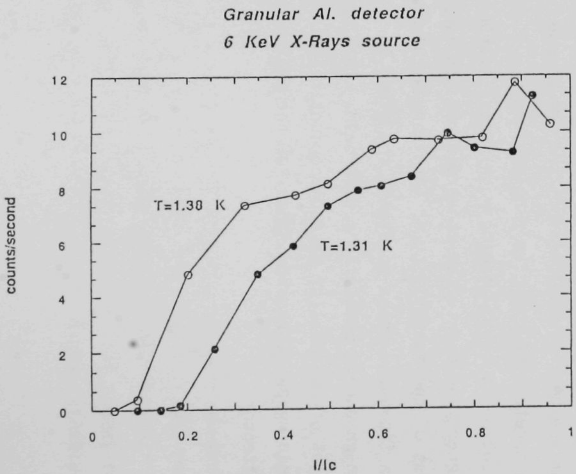


Fig. 20. Superconducting-to-normal switching rate vs. reduced current for a granular aluminum strip exposed to 6 keV x-rays. The reduced current is the ratio of the bias current in the strip to the critical current. Data are shown for liquid helium bath temperatures of 1.31 K and 1.38 K.

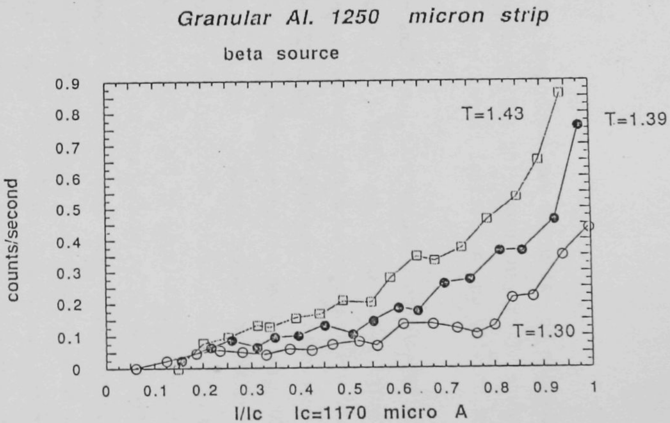


Fig. 21. Superconducting-to-normal switching rate vs. reduced current for the granular aluminum strip when exposed to electrons from a ^{90}Sr source. Data are shown for liquid helium bath temperatures of 1.30 K, 1.39 K, and 1.43 K.

VI. PUBLICATIONS

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C. Zachos (ANL/HEP), D. Fairlie (Univ. of Durham)
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R. St. Dennis (ANL/HEP) ANL-HEP-TR-89-02
Thesis

Single Pion Production in np Scattering
H. Spinka, D. Hill (ANL/HEP), S. Nath et al (Texas A&M Univ.), G. Igo, (Univ. of California), M. Epstein et al (California State Univ.), B. Mayes et al (Univ. of Houston), R. Shypit (Univ. British Columbia), M. McNaughton et al (LANL), J. Birchall (Univ. Manitoba), P. Greene (Univ. Alberta), D. Bugg (Queen Mary College), J. Kruk et al (Rice Univ.), M. Barlett et al (Univ. of Texas) ANL-HEP-TR-89-04
Technical Report

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H. Spinka, R. Garnett, D. Lopiano (ANL/HEP), S. Nath *et al*. (Texas A&M Univ.), R. Jeppesen (Univ. of Montana), G. Tripard (Washington State Univ.), R. Boudrie (LANL), P. Riley (Univ. of Texas) ANL-HEP-TR-89-05
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J. Qiu (ANL/HEP), F. Close (Oak Ridge Laboratory/Univ. of Tennessee), R. Roberts (Rutherford Laboratory) ANL-HEP-PR-89-22
Phys. Rev. D.

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D. Sivers (ANL/HEP) ANL-HEP-PR-89-32
Phys. Rev.

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Phys. Rev. D.

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C.P. Yuan (ANL/HEP), G.L. Kane (Univ. of Michigan) ANL-HEP-PR-89-43
Phys. Rev. D.

A New Method to Detect a Heavy Top Quark at the Tevatron
C. Yuan (ANL/HEP) ANL-HEP-PR-89-44
Phys. Rev. D.

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R. Garnett (ANL/HEP), G. Burleson (New Mexico State Univ.)
ANL-HEP-PR-89-47
Computers in Physics

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ANL-HEP-CP-89-01
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I. Ambats, D. Ayres, L. Balka, W. Barrett, K. Coover, J. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth and J. Thron (ANL/HEP), P. Border et al. (Univ. of Minnesota), W.W.M. Allison et al. (Univ. of Oxford), G.J. Alner et al. (Rutherford Appleton Laboratory), D. Benjamin et al. (Tufts Univ.)
ANL-HEP-CP-89-52
Proceedings of the Tenth and Final Workshop on Grand Unification, University of North Carolina, Chapel Hill, NC, April 20-22, 1989.

The τ One-Prong Problem and Recent Measurements by the HRS Collaboration
J. Repond (ANL/HEP) ANL-HEP-CP-89-53
Proceedings of the 24th Rencontre de Moriond on Electroweak Interactions and Unified Theories, Centre National de la Recherches Scientifique & Commissariat a l'Energie Atomique, Les Arcs, France. March 5-12, 1939.

Soudan 2 as a Long Baseline Neutrino Detector
M. Goodman (ANL/HEP) ANL-HEP-CP-89-54
Proceedings of the Workshop on Physics at the Main Injector, Fermilab, Batavia, IL, May 16-18, 1989.

D. Technical Notes

AMZEUS 77 Stacking of the HAC Section of the Prototype BCAL Module
J. Biggs, A. Buehring, M. Derrick, N. Hill, S. Kaminskas, L. Kocenko, B. Musgrave, E. Petereit, J. Repond, R. Taylor

AMZEUS 78 Stacking and Mechanical Testing of the Prototype EMC Module
J. Biggs, A. Buehring, M. Derrick, N. Hill, S. Kaminskas, L. Kocenko, B. Musgrave, E. Petereit, J. Repond, R. Taylor

AMZEUS 79 Equipment Location and Holes in the T-Beam Region of the BCAL
N. Hill, E. Petereit

AMZEUS 80 Conceptual Design of the Fixture for Calibrating BCAL Modules at Fermilab
N. Hill, E. Petereit

AMZEUS 81 VME-Based DC Multiplexer/ADC
J. Dawson, S. Berg, W. Haberichter, R. Rezmer, J. Schlereth, R. Stanek

AMZEUS 82 Notes on a Meeting Held at Argonne About ZEUS Field Mapping
M. Derrick, A. Buehring, R. Rezmer, R. Stanek, G. Smith

AMZEUS 85 EGS Calculations for the ZEUS Barrel Shower Counters: Effects Arising from the Spacers
J. Repond, P. Zimmerman

AMZEUS 87 Location of Scintillator Panels in the BCAL Stacks of the Production Modules
M. Derrick

AMZEUS 88 EMC Scintillator Sizes for ZEUS Barrel Calorimeter Production Modules
L. Durkin, J. Repond

AMZEUS 89 BCAL Prototype - Observations and Reflections
B. Lu, R. Stanek

CDF-882	Analysis of the Topological Characteristics of Electron Plus Jet Events J. Proudfoot, A. B. Wicklund, F. Ukegawa
CDF-883	A Determination of the Absolute Calibration of the CEM Energy Scale W. Trischuk, L. Nodulman, P. Berge, S. Hahn, J. Hauser, R. Kadel, V. Scarpine, A. B. Wicklund, R. Wagner
CDF-893	Background Energy Correction L. Nodulman
CDF-894	Implications for Top in Low Energy Jets from Gamma-Jet Events R. St. Denis, S. Kuhlmann, L. Galtieri, R. Blair, A. Bamberger
CDF-933	Central Strip Chamber Alignment J. Proudfoot, F. Ukegawa, A. B. Wicklund
CDF-934	Update on Extreme Missing ET Events L. Nodulman
CDF-935	Electron Identification in the CDF Central Calorimeter J. Proudfoot, CDF Collaboration
CDF-948	1988-89 Missing ET Resolution W. Trischuk, L. Nodulman
CDF-962	The Tail of Met Spin L. Nodulman, W. Trischuk, P. Hu
CDF-980	Cosmic Ray Backgrounds to Direct Photons (and Jets) S. Kuhlmann
CDF-984	Jets, W's, and Z's at SQRT(S) = 1.8 TeV S. Kuhlmann
PDK-387	Soudan 2 Nucleon Decay Experiment Quarterly Activity Report, October - December 1988 D. Ayres
PDK-391	The Soudan 2 Proton Decay Experiment J. Thron for the Collaboration
PDK-393	Soudan 2 Nucleon Decay Experiment Quarterly Activity Report January - March 1989 D. Ayres

PDK-394	Soudan 2 as a Long Baseline Neutrino Detector M. Goodman, D. Roback
PDK-395	The Soudan 2 Experiment (Proceedings of the Tenth and Final Workshop on Grand Unification) D. Ayres for the Collaboration
PDK-398	Soudan 2 Nucleon Decay Experiment Quarterly Activity Report April - June 1989 D. Ayres
WF-99	Effective Gradient Enhancement in a Hybrid Wake Field Accelerator J. Simpson
WF-100	Possible Parameters for the SLAC FFTF Beam Monitor (and other issues) J. Norem
WF-101	Multi-stage Wake-field Accelerator W. Gai
WF-102	A Possible High Energy Wake Field System J. Norem
WF-103	Complete Calculation of Wake Field Effects in Dielectric Structures W. Gai
WF-104	Instability of Compensated Beam-Beam Collisions J. Rosenzweig, B. Autin, P. Chen
WF-105	Comments on Transverse Wake-Fields in Waveguides J. Rosenzweig
WF-106	ARRAKIS- A Code for Nonlinear CWFA Simulations P. Schoessow
WF-107	A Coaxial Bunch Compressor for a Photocathode Source C. Ho, J. Norem, P. Schoessow
WF-108	Dielectric Wave Guide M. Rosing
WF-109	Fields in Dielectric Tubes at $\beta = 1$ J. Simpson
WF-110	Argonne Plasma Wake-Field Acceleration Experiments J. Rosenzweig, B. Cole, W. Gai

WF-111 High Power, High Frequency RF Sources
J. Norem

WF-112 Dielectric Loaded Cylindrical Waveguide Accelerator
J. Rosing

WF-113 Recirculating Accelerating Cavities - Maybe?
J. Simpson

WF-114 A Simple Noise Eater for a High Power Laser
J. Norem

WF-115 Scaling of Hybrid Mode Dielectric Transverse Wake-fields
J. Rosenzweig

WF-116 What's a Kilpatrick?
M. Rosing

WF-117 Preacclelerator Design #1: Basics
B. Cole

WF-118 Laser Photocathode Tail Problem
M. Rosing

VII. PUBLICATIONS BASED ON ZGS EXPERIMENTS

The following paper which reported the results of ZGS experiments was published.

ZGS Experiment	Publication
E-447: $\Delta\sigma_L$ Measurements between 1 to 6 GeV/c. (ANL).	Observation of Structures in the Mass Range of 2700 to 2900 MeV in the Difference Between the pp Total Cross Sections for Pure Helicity States I. Auer, E. Colton, W. Ditzler, H. Halpern, D. Hill, R. Miller, H. Spinka, N. Tamura, J. Tavernier, G. Theodosiou, K. Toshioka, D. Underwood, R. Wagner, A. Yokosawa (ANL/HEP) Phys. Rev. Lett. 62, 2649 (1989).

VIII. HIGH ENERGY PHYSICS RESEARCH PERSONNEL

Accelerator Physicists

S. Mtingwa
J. Norem
J. Rosenzweig
M. Rosing
P. Schoessow
J. Simpson

Experimental Physicists

D. Ayres
R. Blair
M. Derrick
T. Fields
A. Gabutti
R. Garnett
M. Goodman
W. Gai
D. Grosnick
R. Hagstrom
F. Lopez
D. Lopiano
E. May
B. Musgrave
L. Nodulman
Y. Ohashi
L. Price
J. Proudfoot
J. Repond
T. Shima
H. Spinka
R. Stanek
K. Sugano
R. Talaga
J. Thron
H. Trost
D. Underwood
R. Wagner
A. B. Wicklund
A. Yokosawa

Theoretical Physicists

P. Arnold
E. Berger
G. Bodwin
J. W. Qiu
D. Sinclair
D. Sivers
A. White
C. P. Yuan
C. Zachos

Engineers, Computer Scientists and Applied Scientists

A. Buehring
J. Dawson
D. Hill
N. Hill
J. Schlereth
W. Wang

Technical Support Staff

I. Ambats
L. Balka
J. Biggs
H. Blair
B. Cole
W. Haberichter
D. Jankowski
T. Kasprzyk
R. Konecny
R. Laird
R. Miller
R. Rezmer
J. Sheppard

Laboratory Graduate Participants

C. Ho
D. Karatas
D. Keubel
M. Laghai
C. Nantista
F. Ukegawa

Appendix A
COLLOQUIA AND CONFERENCE TALKS

D. Ayres

"The Soudan 2 Experiment"
10th & Final Workshop on Grand Unification, Chapel Hill, NC (April 1989).

E. Berger

"W, Z, and Top Physics: Where do we Stand? What Can we Expect in the Short Term?"
Aspen Winter Conference on Elementary Particle Physics, Aspen, Colorado. Invited review (January 1989).

"W, Z, and Top Physics--Status and Near-Term Prospects"
Argonne National Laboratory, High Energy Physics Division Seminar (January 1989).

"Heavy Quark Production at Fixed-Target and Collider Energies"
University of Virginia, Nuclear and Particle Physics Seminar (January 1989).

"W, Z, and Top Physics--Status and Near Term Prospects"
Princeton University, Elementary Particle Physics Seminar (February 1989).

"W, Z, and Top Physics--Status and Near Term Prospects"
Michigan State University, Elementary Particle Physics Seminar (March 1989).

"Spin/Polarization Physics at Fermilab"
Main Injector Workshop, Fermi National Accelerator Laboratory (May 1989).

"Phenomenology of Heavy Quark Production"
Invited plenary review, IX International Conference on Physics in Collisions, Jerusalem (June 1989).

"Bottom Production in Hadron Collisions: Theory"
Invited plenary review, Workshop on B-Factories and Related Physics Issues, Blois, France (June 1989).

S. Kuhlmann

"JETS, W's and Z's from CDF"
Les Arcs, France (March 1989).

E. May

"Portable Parallel Programming in a FORTRAN Environment"
Oxford Computing Conference (April 1989).

S. Mtingwa

"Novel Methods for Accelerating Charged Particles"
Lebedev Physics Institute, Moscow, USSR, January (1989).

"New Applications of Plasmas in Accelerator Physics"
Leningrad Nuclear Physics Institute, Gatchina, USSR (March 1989).

"Novel Methods for Accelerating Charged Particles"
Yerevan Physics Institute, Armenia, USSR (May 1989).

L. Nodulman

"CDF Detector Performance & Plans
Collaboration Upgrade Workshop, Fermilab (March 1989).

Y. Ohashi

"Direct Photon Experiment at POLEX (UNK)"
Institute for High Energy Physics, Serpukhov, USSR (March 1989).

"Polarized Proton and Antiproton Beams at Fermilab"
Nagoya University, Nagoya, Japan (February 1989).

L. Price

"SSC Overview"
Argonne National Laboratory (May 1989).

"SSC Detector Design Meetings at ANL"
Fermilab (June 1989).

J. Repond

"Is There a τ 1-Prong Anomaly?"
Northwestern University (February 1989).

"The τ 1-Prong Problem and Recent Measurements by the HRS Collaboration"
XXIV Recontre de Moriond, Les Arcs, France.

P. Schoessow

"Wakefield Acceleration Experiments"
Texas A&M University (February 1989).

H. Spinka

"The Nucleon-Nucleon Program at LAMPF"
Argonne National Laboratory (January 1989).

R. Talaga

"Ultra-Energetic Cosmic Gammas and the Muon Surplus"
Fermilab (February 1989).

R. Wagner

"Current Results from CDF"
"Search for Supersymmetric Particles at CDF"
12th International Workshop on Weak Interactions and Neutrinos, Ginosar, Israel (April 1989).

C. Yuan

"Collider Phenomenology"
Argonne National Laboratory (June 1989).

C. Zachos

"Lectures in Conformal Field Theory"
Ohio State University (April 1989).

"SU(∞), Sine Brackets, and Infinite-Dimensional Algebras"
University of Miami (February 1989)
Ohio State University (April 1989)
Texas A&M String Conference (March 1989).

"Hamiltonian Flows, SU(∞), SO(∞), Usp(∞), and Strings"
Lake Tahoe Conference on Physics & Geometry (July 1989).

Appendix B
HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

E. Berger

Scientific Program Committee, XXIV Recontre de Moriond, "New Results in Hadronic Interactions," Les Arcs, France, March 1989.

Elected Vice-chairman, Executive Committee, Division of Particles and Fields, American Physical Society, 1988 -

Program Chairman, Division of Particles and Fields, American Physical Society, 1989. Responsible for the organization of invited paper sessions in Particles and Fields at the Spring Meeting of the APS, Baltimore, May 1-4, 1989.

International Program Committee, DPF 90, General Meeting of the Division of Particles and Fields of the American Physical Society, January 1990.

Co-chair, Working Group on "Theoretical Issues for the 1990's," Workshop on Physics at Fermilab in the 1990's, Breckenridge, Colorado 1989.

Chairman, Working Group on Hadronic Physics, NSC Nuclear Physics Long Range Planning, 1989.

Department of Energy Review of the High Energy Physics Program at the Lawrence Berkeley Laboratory, June 1989.

Chairman, Organizing Committee, DPF Snowmass Summer Study, 1990.

Scientific Program Committee, XXV Recontre de Moriond, Les Arcs, France, March 1990.

Organizing Committee, Workshop on Structure Functions and Parton Densities, Fermilab, April 1990.

M. Derrick

Board of Supervisory Editors of Nuclear Physics B.

T. Fields

Member of HEPAP Subpanel on Major Detectors in Non-accelerator Particle Physics (March 1989).

E. May

HEPNET Technical Coordinating Committee.

L. Price

Users Organization for the SSC Executive Committee: Secretary-elect

International Advisory Committee for Generic Detector R&D for the SSC

ESNET Steering Committee

SSC Computing Task Force

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